THE COLOR OF LIFE

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THE COLOR OF LIFE

BY ARTHUR G. ABBOTT

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THE COLOR OF LIFE

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To

MY MOTHER

PREFACE

Color has been used by nature lavishly, purposefully, and effectively since the creation of our earth. Since his own creation, man has used it more or less lavishly, purposefully, and effectively. Primarily he has made use of it because he likes it, has been pleasantly fascinated by it, and has found it to be an agreeable companion. Recently, with general advances in science, man has found color to be a valuable assistant in the performance of his daily work.

In the history of man, color has always been and always will be associated with various arts, but its associations have become widened with the advance of civilization until today it is recognized as a great natural force, an important and indispensable element of our daily lives. Through its power to influence human behavior, it is working every day for the benefit of mankind all over the earth. Its usefulness as a guide to information is being employed by a multitude of scientists, investigators, and other seekers after facts in many fields.

As its qualities are recognized, better understood, and more widely and intelligently applied, color may help to effect a change in the nature of humanity. If that is possible, it can be instrumental in diminishing man's most unnatural and unprofitable traits and increasing the better ones. At any rate, since it is at this moment a very important element of life and is contributing tremendously to the progress of humanity, to find out as much as can be known about it is desirable and profitable.

While man has observed much about color, the various conclusions that he has reached are not necessarily facts. Man will continue to discover truths about color and other things as he continues to search for them by observing, experimenting, and reasoning. Ideas about scientific matters are subject to change as new observations and discoveries are made.

Color has been an element of life since the creation, but the

science of color as we know it today is comparatively young. There is much to be learned and much to be done about it.

ARTHUR G. ABBOTT

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LIST OF COLOR PLATES

A NOTE TO THE READER

Color, a constant companion of nearly all forms of life on this earth, has, like other great forces, potentials of good and of evil. It is our privilege, perhaps our duty, to learn to use it for good as much as possible. Woven into our modern civilization in such a way as to be an integral part of it, color can be taken for granted, but it cannot be ignored. The sudden removal of all color would produce chaos until vast readjustments were effected, not only in human affairs but in those of almost all other creatures associated with man.

Since its influence is manifested largely through the sense of sight, the power of color is most effective when this sense is keen. The faculty of seeing, in normal individuals, can be cultivated and sharpened by mental concentration and practice. It is a real pleasure to *see* a dramatic sunset, a colorful chorus on the stage, or a beautiful flower. But *seeing* anything involves more than looking at it. Such perception is a mental process, which for most of us requires conscious effort. After a period of self-training or, better, of competently guided training, the average individual can see that which he looks at. The color of life then takes on a new meaning. It ceases to be just another inescapable factor of existence and becomes one of the most pleasurable and constantly thrilling experiences of life.

Some professional groups have been trained in this ability because it is a necessity in their work. It is thus essential to a competent artist, a naturalist, a criminal investigator, a news reporter, a doctor of medicine, and to many others whose livelihood depends on accurate seeing. Such persons have developed a "visual memory." The general training procedure is to look at an object or a scene carefully for perhaps a minute or two at first, then to turn away from it and try to recall and describe what was seen. Art students in some instances have been trained to look at an object for a short period of time, then, after the object has been removed, to paint from memory what they have seen. From the

observation and reproduction of some simple object, they may progress gradually to such studies of a costumed figure. The time of observation is gradually cut and the complexity of the situation increased until the student is expected eventually to sit in a darkened room before a screen on which are rapidly flashed a series of projections involving form, shading, and color and, when the room lights are turned on, to make quick sketches of what he remembers. The number of separate objects may be as much as 10 and the time of observation may be as little as 10 seconds for each.

In your own case, all that you need to do is to observe a single object as long as you wish, write down or describe to someone what you remember of it, then check on your ability to see. You will probably find that you need considerable practice. Eventually, however, you will be able, after passing a person in the street or being introduced to someone — a matter of seconds — to recall later the color of that person's hair, eyes, apparel, etc. Although this will require an effort at first, it can develop into a desirable habit that will enrich your life. You will enjoy and remember particularly interesting color combinations seen in nature and elsewhere; you will become discriminating and develop the ability to use color effectively in many ways.

Besides being a source of enjoyment, color is now being harnessed to industry and is proving to be a most valuable aid in production and in the selling of merchandise and services. It is abundant, inexhaustible, tireless, and as permanent as the material from which it springs. Atomic energy may sometime replace coal and petroleum, but nothing can ever replace color. It is itself a manifestation of atomic energy. It is as permanently established in the scheme of life as the air we breathe or the water we drink. If man survives on earth, 10,000 years from now color will still be his inseparable companion. Through the years, it will contribute more and more to his progress.

This book is not intended to be a guide for any science, trade, or profession, but a source of pleasure and profit for the average man, woman, and child through the obtaining of a more intimate knowledge of one of the most vital forces of life. The purpose of this book, therefore, is to present a variety of facts, theories, ex-

periences, and observations about color that will be interesting and useful to a large number of people.

It is hoped that the theories and facts presented here will help the reader to a better understanding of color and, by means of examples of its use, to a realization of its present importance and future possibilities.

The suggestion is made that, after you have read this book, you procure a large scrapbook, index it to correspond with the parts of the book, and collect colored prints to illustrate these different sections. Provide yourself also with a small set of colored cutting papers, such as were used in making the charts for this book. They can be purchased from various supply houses.

At first you may not readily recognize suitable material, but eventually you will find prints in magazines and advertising matter that will have an appropriate place in your collection. Whenever you see especially pleasing combinations of color, make a mental or written note of them. On returning home, find the colored papers in your set that correspond; cut off pieces and paste them in your book as a permanent example of any harmony that has appealed to you. Consideration should be given to hue, value, and chroma and to the proportions of each color, as all these factors are important.

Your purpose in collecting prints in this instance will be primarily to illustrate this book. Besides having enjoyment in doing this, you will find it a help to a better understanding of color and to the development of your ability to use color. It may easily expand into a lifetime hobby or supplement some hobby that you already have. At any rate, it will be a contribution of your own, and the benefits derived will be in proportion to the efforts expended.

PART ONE

The Foundations of Color

I

LIGHT AND MATTER

WITHOUT LIGHT there would be no visible evidence of color. So let us first consider the light from our sun, which is known as "electromagnetic radiation." Scientists believe that the sun like all matter in the universe is composed of atoms. An atom is considered the smallest part of an element that can exist, although each atom is in itself a miniature solar system. Each atom is composed of (1) particles having positive electrical charges (protons), (2) particles having negative electrical charges (electrons), and (3) particles having no electrical charge (neutrons).

As the planets revolve about the sun in our solar system, the electrons revolve about the protons and neutrons in an atom. This movement in an atom is in some instances with a speed of 1,500 miles per second. It creates heat and in turn causes one or more electrons to leave the atom (ionization). However, the proton promptly recaptures such electrons and does so millions of times each second. Every time an electron is recaptured, the energy of its former motion is set free as a unit beam or "quantum" of radiation (photon). These photons move from the center to the outer limits of the sun and then fly off into space, moving with a speed of about 186,300 miles per second. This is the velocity of light when traveling through ether and the earth's atmosphere, but it is slowed down in passing through denser matter such as water. Thus a ray of light requires a bit less than 8½ minutes to make the journey from the sun to the earth.

Light travels in waves and is transmitted by ether, the medium that fills all space. It travels in a straight path unless it meets with interfering matter. This interference may cause the light ray to be bent, broken, or scattered, depending on the nature (molecular composition) of the matter met with. We have all seen sunlight entering through a small opening into a dark room. If the atmosphere of the room is clear, we see only the spot of light as reflected from the floor or the wall that it strikes; but if dust is in

the air, we see the complete beam as the light is reflected from the dust particles and we note that it travels in a straight path and is radiating from the sun.

Light can be both beneficial and harmful. It permits us to see but it can blind us. It is essential to life but it can also destroy life.

The length of the waves of light vary greatly. The length of a wave depends on the amount of energy that created it and determines the color sensation that is produced by it. Only a small percentage of all radiant energy contributes to the sensation of visible color. Scientists have divided the solar radiant energy into the following groups, from the shortest to the longest wave lengths: gamma rays, X rays, ultraviolet rays, visible rays, infrared rays, Hertzian rays, and radio waves. These waves are measured by meters or parts of meters. A meter corresponds to 39.37 inches. Radio waves measure from 200 to 600 meters in length. Visible rays (contributing to color as man sees it) measure from 400 to 770 billionths of a meter. These measurements are expressed in millimicrons, each of which is one billionth of a meter. In spite of these minute measurements, the wave length of radiant energy can be measured more accurately than can any other of its physical qualities.

The exact color sensation created depends on the wave length of the light and its corresponding rate or frequency of vibration. Since all light travels at the same rate of speed and there is the same interval between every two waves, the shorter waves vibrate more often in the same period of time than do the longer waves and thereby create a different color sensation. The measurement of wave lengths of light visible to man coming from the sun are approximately as follows:

Color	*Millimicrons*	*Color*	*Millimicrons*
Violet	400	Yellow	570
Blue	460	Orange	590
Blue-green	490	Orange-red	650
Green	500	Red	750
Yellow-green	550		

Radiant energy emanates not only from the sun, but from all luminous bodies. Among these are stars, comets, meteors, flames,

sparks, electrical disturbances, gases, phosphorus, etc. Light is usually accompanied by heat. The longer the wave, the greater the heat.

All matter upon which light falls absorbs part of the light and a corresponding amount of its heat. The elements of the matter and the arrangement of its molecules determine what part of the light will be absorbed, reflected, or transmitted by it. The nature of the matter will also determine whether it will bend (refract), break (diffract), or scatter (disperse) the rays of light falling upon it and to what extent. In passing from substance of one density into that of a different density, light is refracted. From the degree of such change in direction scientists have determined the refractive index of various substances. This index for air is 1.0003, for water 1.333, for linseed oil 1.49, for glass 1.50 to 1.96, for diamond 2.47. These indexes result from the use of yellow light. The index is different for light of different wave lengths, and this accounts for the separation of white light in passing through a prism of glass. In 1666 Isaac Newton caused a beam of sunlight to pass through a glass prism to demonstrate that a part of sunlight is composed of various colors.

In an ordinary beam of light, vibrations occur equally in all planes at right angles to the axis of the wave. Such a beam has no "sides" and is symmetrical about the direction of propagation. When such a beam strikes a mirror obliquely, that part which is vibrating at right angles to the plane of incidence will have its motion parallel to the surface and be reflected, while the other vibrations will penetrate the surface of the glass. The result of reflection therefore, is to separate the original beam into two parts and the reflected ray will vibrate in a single, fixed plane. Light modified in this way is said to be *plane polarized* by reflection. Complete separation or polarization is effected when the refracted ray makes an angle of 90 degrees with the reflected ray. A beam of light can be likewise separated or polarized by passing through various crystals that have doubly refracting power.

Some crystals and many organic liquids have the property of rotating the plane of polarized light that passes through them. A plane-polarized ray upon entering such a medium is converted into two *circularly polarized* rays. Such vibrations differ in phase by a

quarter period. When the difference in phase is other than a quarter period, the beam is said to be *elliptically polarized.*

A polariscope is an instrument containing two specially prepared calcite (Iceland spar) prisms by which polarized light is produced and studied. If plates of crystalline material are placed between the two prisms and the polariscope is provided with a lens for projecting a conical beam of light on a screen, many extremely beautiful symmetrical patterns of exquisite color can be observed. It is remarkable what color displays can be effected with lowly crystalline substances that normally reflect little or no color. By means of polarized light, points and degrees of stress and strain can be seen and studied on isotropic substances as they are twisted, pressed, heated, etc. The movement effects various color changes.[1]

Polaroid sunglasses and Eastman Pola-screen for photography are screens produced by countless minute, rodlike crystals arranged parallel to each other. The sheet material, cemented between glass plates, polarizes the light to the extent that glare is largely eliminated.

The color of some matter is due to the presence of pigment in or on its fibers. Pigment is separate matter that has the power of selective absorption of light rays. Pigment can be separated from the other matter in or on which it is deposited and can be manipulated by man. Matter depending on pigment for its color appears to have the same color in any position or with any movement and gains or loses color only with a gain or loss of pigment. However, some matter is nearly devoid of pigment yet displays brilliant colors. Such matter depends on the structure of its surface—minute outgrowths, threads, scales, mounds, or other projections whose interference of the light rays brings about sensations of color. Many leaves and flowers offer examples of pigmented matter. The feathers of certain birds, wings of some insects, and mother-of-pearl provide examples of matter depending primarily on surface structure for coloring. Such coloring changes with every movement and may embrace the whole spectrum.

[1] See the article on Polarization in the Encyclopedia Americana, 1943, published by Americana Corporation, New York and Chicago; and the article, "Photography by Polarized Light," by J. W. McFarlane, in the *American Annual of Photography*, 1937, reprinted in the Smithsonian Institution's *Annual Report*, 1937, U.S. Government Printing Office, Washington, D.C., 1938.

Opaque matter reflects most of the light that is not absorbed by it. Transparent matter transmits most of the light that is not absorbed by it. This action of matter on light contributes to the appearance of color. Sunlight, before it strikes matter, is composed of rays of all wave lengths and normally is considered to be white light. No matter absorbs or reflects all light of any particular wave length, but that matter which reflects the greatest percentage of white light is called "white." Likewise, that matter which absorbs most of the white light is called "black." Black matter absorbs a maximum of about 95 per cent of the light and also of the heat that accompanies the light.

A glazed or a highly polished surface may reflect practically all of the light that falls on it, in which case we see an image (reflection) of the light itself or of some object that is reflecting the light. Some of the reflected light may remain unchanged, but most of it penetrates a short distance beneath the surface of the matter on which it falls and is affected by irregularities that it encounters there.

Matter that absorbs most of the yellow and red rays and reflects or transmits most of the blue rays appears to have a bluish hue. Matter that reflects most of the red rays and absorbs the others appears to be red. The intensity of the hue depends on the amount of light of that wave length which is reflected.

In the rainbow, nature breaks up the sunlight and shows us its various parts. Man can do the same thing with a crystal prism and by other means. In passing through a prism, a beam of sunlight is dispersed so that upon emerging the separate rays are arranged in order of their wave lengths. The resulting range of visible light is known as the "solar spectrum." This is the color harmony chart supplied to us by nature and is the supreme guide for the study and use of color.

Acknowledgment is given to the following sources of information. See also Part Seven.

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2

SIGHT

Although color exerts influence in various ways, man can sense it only by vision. He cannot feel, hear, smell, or taste it; so a brief consideration of the faculty of seeing should be helpful toward gaining a better understanding of color. We see because the retina of the eye is sensitive to light and transmits to the brain, by means of nerves, the impression that it gets. The retina of the average normal eye is capable of receiving two kinds of impressions from light. The first of these is the impression of light and dark, or of degrees of illumination (achromatic or colorless sensation), from white through all grays to black. We may be able to distinguish about 600 different degrees of lightness or darkness. The second impression is that of color or hue (chromatic sensation), from red through orange, yellow, green, and blue to violet, in many shades and tints. It has been estimated that we can distinguish several hundred thousands of such impressions, perhaps millions.

These impressions are said to be received by about 137 million sensitive nerve fibers in the retina. Of these, 130 million are known as "rods" and 7 million as "cones." The rods are sensitive only to light and dark; the cones, only to hue. The impression received by these nerves is relayed by connecting nerves to the cerebral center of visual sensation located in the occipital region of the brain. Exactly what happens and how it happens before and after the brain gets this report from the eye is still much of a mystery. It is known that changes take place in the body, depending on the sensitiveness of the system whereby one feels a sense of pleasure or displeasure, comfort or discomfort, ease or strain, relaxation or tenseness, depression or elation, stimulation or depression, etc. All these changes affect various organs of the body, influencing their action and, therefore, man's behavior.

Between the retina and the wall of the eyeball is a black pigment with which the tips of the rods and cones make contact. In the

rods is a red pigment known as "rhodopsin," or "visual purple." This is said to be formed from a yellow pigment known as "retinene" and the almost colorless vitamin A.

It is believed that light effects three kinds of change when it strikes these pigments and organs: (1) *electrical charges*, which travel along the nerves; (2) *physical contraction* of the cones and swelling of the rods; and (3) *chemical changes*, in which the retina tends to become more acid and wherein the visual purple bleaches. Another thought is that the photochemical substance in the rods and cones decomposes under the action of light and becomes re-formed in the dark. The effect is practically instantaneous except at the beginning and at the end of exposure.

We remind you that this explanation is theory. There are other ideas, none of which has as yet been proved to be fact. Thomas Young in 1807 suggested that there are in the eye three sets of nerves, which are sensitive to three overlapping regions in the spectrum—one set having a maximum sensitivity for the blue part, another for the red, and another for the green. This was the foundation of the Young-Helmholz theory.

The retina is sensitive to light only within a limited range. Light waves, of which there are more than 65,000 to the inch and which vibrate more frequently than 770 billions of times per second, make no impression on the human retina and are, therefore, invisible to man. Light waves, of which there are fewer than 35,000 to the inch and which vibrate less frequently than 400 billion times per second, are also invisible to man.

It is possible for the retina to convey an impression of light to the brain when light is absent. Pressure or a blow on the eyeball when the lid is down may give an impression of light. Also, a severe blow on any part of the head may give impressions of light ("seeing stars").

The rods and cones are somewhat slow in their reaction to the stimulus of light. Light rays vibrate some time on the retina before the rods and cones start relaying the impressions to the brain. Likewise they continue to convey impressions after the light has been removed. The nerves are said to respond most quickly to the arrival and departure of blue rays, next to the red, and least quickly to the green rays. In any case the waking seems to be with a start,

because the most vivid impression comes in the first fraction of a second.

The nerves of the retina are easily tired. This leads to various common sensations, one of which is the afterimage—a visual impression following the removal of the stimulus. For instance, if you look only briefly at the sun, a flame, or some other source of light, you continue to "see" the light with your eyes tightly closed. If, after looking fixedly for a time at an object, you suddenly close your eyes, you will at first continue to "see" the object as it originally appeared. But the nerves of the eye have become tired and, although they do not stop work, they shift the imaginary burden over to the other shoulder, as it were, and tell the brain that they are receiving an exactly opposite impression. The positive appears negative and the negative positive. A red object in the afterimage appears blue-green and, likewise, all other colors assume their complementary hues. These opposite impressions may be received with the eyes open, as well. Look steadily at a spot of color or a black-and-white design, then shift the gaze suddenly to a white area. You will then get an impression that is exactly opposite to what you have been looking at. Look steadily at a bright-green spot and then look at a white or a gray area. On that area the spot now appears pink. The theory in this instance is that the nerves affected by green have become tired and that, when the eyes are turned to a neutral area, only the untired nerves respond.

The organs of sight are subject to many irregularities and are being "fooled" constantly. A red surface and a violet surface at the same distance from the eye do not appear to be so. The red surface appears to be nearer. In a bright light, red appears more intense than blue, while in a weak light the same blue appears more intense than the same red. As light fails (as is the case with the setting sun), reds disappear first and appear black, while blues and violets appear brighter and greens become gray. If you approach a red and a green light from a distance in the dark, the green (or blue) light can be distinguished as a light before the red one can be perceived. However, the color of the red light will be distinguished before the color of the green one can be. These are a few of many illusions common to normal eyesight. Many human

beings are known to be color blind to some degree. It has been estimated that about one man in every 20 and one woman in every 200 is more or less blind to red or green or to both of these colors. Almost no one is blind to yellow, blue, and violet and the majority of people can distinguish orange. No completely satisfactory explanation has as yet been given for the cause of color blindness. It may be due to a deficiency of some substance in the body or to a mental condition that can be adjusted.

David Dietz, science editor of the Scripps-Howard papers, reports:

The human eye is most sensitive to the blue-green part of the spectrum in dim light and to the yellow portion in bright light. This fact was first noted more than a century ago, but no adequate explanation was forthcoming until the present time.

The phenomenon was originally discovered over 100 years ago by the Czech anatomist, Johannes Evangelista von Purkinje, who studied the eye and the brain in particular and after whom the large cells of the front part of the brain were named Purkinje's cells.

He noted, when walking in the fields at dawn, that blue flowers tended to appear brighter than red, while in full daylight the red flowers looked definitely brighter than the blue.

We know now, as Dr. George Wald, Harvard University biologist and authority on vision, points out, that this is due to the dual mechanism of the eye (rods and cones).

The light-sensitive material in the rods is most sensitive to blue-green light. That is, it absorbs those colors most strongly.

On the other hand, the light-sensitive materials in the cones absorb yellow light most efficiently.

Regarding rhodopsin, the pigment in the rods that enables the eye to see at night, Dr. Wald has made some interesting discoveries. It has been known that rhodopsin does not regenerate properly if there is a vitamin A deficiency.

Experiments in Dr. Wald's laboratory showed that partial night blindness began to be noticeable after a 24-hour deficiency of vitamin A.

In connection with color blindness the following Associated Press dispatch, dated Oct. 4, 1944, presents one school of thought.

A Baltimore physician, reporting a cure for supposedly incurable color blindness based on the theory that the affliction is mental and not

physical, cited today as proof of his success nine young men now in the Army Air Forces.

Dr. Israel Dvorine, who described his method as a retraining of the eyes with color charts, said that he was successful in 9 cases out of 12 and that the three who failed "just didn't want to try."

He has published two books containing more than 400 charts that he developed and painted with water colors during the treatment of his young patients. One book is for testing, the other for treatment.

Different patients require different charts, he found, and his complete set covers the entire spectrum, in pairs and in varying tints and shades.

"The only medical idea of how we distinguish colors is that there are nerve ends in the eye that are able to tell them apart," he explained.

"But I have found there is more to it than this. . . . I believe color blindness, especially the inability to distinguish between colors side by side is mental, not a nerve trouble, and like any other mental deficiency it can be educated away."

Dr. Dvorine explained that in the training method "there are three steps. The first is to show the student or patient a figure, say, in red on a green field, the figure being plainly separated from the green. . . . He is told what the colors are and studies this chart repeatedly.

"The second step has the same number blended into the green background. . . . The third chart has the colors perfectly blended. . . .

"The test is then repeated with green on red, and so on through the whole rainbow of colors and two added for good measure, until the student is letter perfect."

Faber Birren in his book "Selling with Color" states that some types of color blindness are heritable and that about 1 per cent of women, 4 per cent of white men, 3 per cent of Negroes, and 2 per cent of Indians have been noted to be color blind to some extent.

Color is not essential to sight, but it makes things easier to see and gives vitality and interest to form. The lives of most human beings and of nearly all living things would have to be radically adjusted if the element of color were removed. About 5 per cent of all persons are said to have definite associations between certain musical sounds and certain colors. There is little uniformity of sensation, so such associations may not be of any general use. Overexposure to the invisible ultraviolet rays can produce a severe irritation in the eyes, which might develop into conjunctivitis.

Overexposure to visible white light, such as that reflected from snow or sand, can cause blindness.

Although in this book we are primarily concerned with color as man sees it, a few remarks about color and sight in connection with some of the other creatures on earth may be of interest. Most animals, birds, and fishes have two eyes each, which function much as man's eyes do. The construction and operation of the eyes of insects, however, are vastly different. There are some creatures on earth that have no eyes at all. Among these are certain worms, reptiles, and fish that live permanently in total darkness.

Although most mammals sense color, it is believed that horses, dogs, cats, bulls, bats, hedgehogs, moles, night apes, rats, and mice cannot distinguish one color from another. They are said to have no cones in the retinas of their eyes. Most fishes have some cones, rays and dogfish being exceptions. In most reptiles only cones are found, while in the eyes of most birds there are both rods and cones and usually the cones are greatly in excess of the rods, which results in the birds' possessing a very keen sense of color. It has been noted that this sense is especially active toward the red end of the spectrum.

An exhibit at the American Museum of Natural History in New York, in January, 1940, conveyed the idea that chickens can see only color and that the housefly's vision is purplish and spotty. Nocturnal birds and animals have a predominance of rods, and this gives them a very keen sense of light, whereas the diurnal types are more concerned with colors and are equipped with more cones. No creature can see anything in absolute darkness. Cats, owls, and some other creatures see easily at night because they can dilate the pupils of their eyes and admit more light and because they have more rods in the retina to receive what light there is. The light is there, although we cannot see it. Some insects are unable to see some of the colors that we do but, at the same time, can see colors that are beyond our range of vision.

Professor K. von Frisch states that bees can recognize orange, yellow, green, violet, or purple, but that they are blind to the color red. On the other hand, he found that bees are able to perceive ultraviolet rays, the ultraviolet being a special color for them, distinguishable from blue and from other colors. Professor von Frisch

says, however, that the most important factor in enabling bees to recognize the different species of flowers is their remarkable sense of smell. This, he explains, is why a bee, on a given individual trip, always visits definite species of flowers.

Charles Eliot Perkins advises as follows:

> I have conducted several series of experiments during the last twenty years on the phenomena of light, and one of these series, from 1933 to 1937, consisted of a set of experiments, in my laboratory and in the field, to determine the reactions of various species of insect and mammalian life to color.
>
> One of the interesting things revealed during these experiments was that honey bees, apparently, have no sense of color, but select various flowers, unerringly, solely by sense of smell. Most bees are specialists, in that they will prefer to gather honey from one species of flower, or plant, and they are attracted to their particular choice by a very sensitive and selective olfactory mechanism. For instance, if a given bee is turned loose in a garden where there is a great variety of flowers of different colors, that bee will gather pollen from only one type of flower, usually having the same color. Having discovered this I, at first, thought that the bee was attracted to the flower by its color. After many painstaking experiments on a horticultural estate in New Jersey (the Henderson Seed Company's farm, and the New Jersey Horticultural Society's experimental farm) I found that this was not the case. Bees locate their choice flower by smell and not by color, and they find their hive, as the ants find their mound, by their sense of smell.
>
> Another interesting discovery was that there is a relation between the color of an insect, or of an animal, and its voluntary selection of environment. In the case of the butterfly I found that most species will center their attention on flowers that have colors that predominate in the coloring of the butterfly's wings. This is instinct and not chance or volition on the part of the individual insect. It is evident that certain color vibrations emanating from the flower answer a responsive receptor in the involuntary nervous system of the insect, which causes it to favor that flower. The sense of smell apparently has nothing to do with it, for many species of butterflies prefer plants and flowers that have no odoriferous content.

Faber Birren in "Selling with Color" states that most insects begin to see color at yellow and that their range of vision extends

through and perhaps beyond ultraviolet; that they do not see red and orange as we do; that a blue light tends to attract most insects, but that red and yellow light does not. He states, however, that experiment has shown that more Japanese beetles are caught in traps painted bright yellow than in those of any other colors.

Thus the relation of color to various forms of life varies according to their sensitiveness to it. This sensitiveness in most forms of life depends largely on their powers of vision, although science has demonstrated that color also exerts influence in ways independent of vision, as is described in later chapters.

Acknowledgment is given to the following sources of information. See also Part Seven.

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PART TWO

Colors by Nature and How Produced

3

THE HEAVENS

NATURE IS the supreme colorist, the moody master of harmony. For most of the tiny creatures who move about the earth's surface she provides a continuous performance with her colors. She paints her moving pictures in miniature as well as on a grand scale; but size is always impressive and the average observer is likely to be more moved by her grand effects. No uncommon intelligence is needed for the enjoyment of nature's "works of art," but enjoyment can be increased by some degree of understanding.

Among the grand-scale color effects of nature are those that are manifest in the sky. If the air, or atmosphere, were perfectly transparent, the sky would appear to us to be black. However, floating about in the air there are particles of matter that intercept the light from the sun and scatter it to some extent. Because the violet and the blue rays are most widely scattered, we get the sensation of blue when we look at the sky on a clear day. But with a congestion of particles and moisture, a foggy screen comes between us and the sun and we see variously grayed skies, according to the kind and quantity of matter suspended in the atmosphere. It is estimated that nitrogen constitutes about four-fifths of the atmosphere, while oxygen accounts for the remaining fifth; but other matter also is present. No great amount of light is absorbed by any of the matter, but the light is mainly scattered about by reflection.

Because there is a greater concentration of matter nearer to the earth's surface, the sky appears less blue nearer the horizon than it does overhead. From the summit of a high mountain, the sky overhead seems to be darker blue than it does from water level. This is due to the presence of finer and less concentrated matter in the atmosphere at that point than below. If one went beyond the earth's atmosphere, the sky would lose its blueness and look black. Seen from the moon, it would appear black, because that satellite

has no atmosphere and no suspended matter about its surface, as our earth has.

The colors of the sky range from the near whiteness of dawn to the near blackness of night. The first rays of the morning sun gently and gradually penetrate the darkness; the coming of the light is more gradual than its disappearance. The colors of sunrise are at first very delicate and pale, rather "cool" tints. When the sun itself appears, it is often ruddy, sometimes very red; but seldom, if ever, is it accompanied by the riotous colors of sunset. While the factors bringing about the appearance of sunrise and sunset are similar, the sequence of events is reversed.

The appearance of the sun and the sky depends upon the atmospheric conditions through which the light rays come to the eye. With a declination of the sun, the sky overhead becomes a deeper, more violet blue. Closer to the horizon it takes on a yellowish-green tint. Near or at the horizon it becomes a yellowish pink. As the sun continues to sink, its rays come to us through a greater concentration of interfering matter, which absorbs most of the blue rays and passes on the red and the yellow rays. The sun, which appeared at noon as a white disk, has now become a ball of fiery red surrounded by brilliant colors.

The apparent colors of the landscape change with the setting of the sun. The hills become dark blue and purple, the blues appear brighter, the greens become gray, and the reds appear black. In the eastern sky, accompanying sunset, there is a pinkish counterglow, below which appears a dark band. This is the shadow of the earth on the atmosphere. Beams of sunlight breaking through clouds are parallel. They appear to radiate because of perspective.

With the coming of night, the stars, when they are not obscured, provide a pale illumination; but this is scarcely strong enough to make it possible for us to distinguish color. The comparatively bright sunlight reflected by the moon is not enough to convey more than a very limited range of color impressions to us. All colors by moonlight tend to look like dark or violet blue. In bright moonlight green foliage appears silvery gray. This is probably due to the absorption by the moon of most of the long rays from the sun and the reflection of short rays. A low-lying moon in a haze has a ruddy appearance, because the intervening matter stops

the rays that have short wave lengths and transmits the fewer rays that are of long wave lengths, reflected by the moon. In such a case the sky near by also has a reddish to violet appearance and shadows in the landscape take on a deep-purple tone. Moisture in the atmosphere causes moonlight to appear greenish. When either the moon or the sun is observed through a thin cloud of ice crystals, a halo is seen around it. This is usually white but, when it has color, red is inside, yellow next, and green on the outside. When the moon or the sun is observed through a light vapor cloud, a corona can be seen around it. In this case the position of the red is on the outside.

Reflection of light from concentrations of condensed vapor (water particles) a considerable distance away in the sky presents clouds. The small water particles by their shape and constitution reflect all the light, of any wave length, that falls on them. In full sunlight, when they are high in the sky, clouds appear white. Those of a lower level may appear yellowish with bluish shadows. When they accompany the sunrise or the sunset, clouds reflect the light from the sun and the reflected rays, as they pass through the atmosphere, are absorbed, reflected, and transmitted as has been already described.

A beautiful and familiar color display in nature is that of the rainbow. When the atmosphere is charged with drops of water, the sunlight falling on them and passing through them is split up and emerges in all its separate parts, which are seen arranged in the order of their wave lengths. This action takes place because the water particles, being denser than the surrounding air, cause the light rays to bend. The rays emerge separately because of the shape of the water drop and because the degree of bending depends on the wave length of the light. Under normal conditions the whole solar spectrum is exhibited in the rainbow. The position of the rainbow is opposite the sun, where it forms an arc across the field of vision in conformity with the earth's curvature. This arc is usually less than a semicircle. The higher the sun is, the shorter the segment appears. On the arc are displayed the spectral colors from violet on the inside, through blue, green, yellow, and orange, to red on the outside. In a secondary bow or arc, sometimes seen at the same time, the order of the colors is reversed, the red being

on the inside curve and the violet on the outside. The bands of color appear wider or narrower under different conditions, the width increasing as the size of the water drops decreases. Maximum illumination results from a minimum of deviation. The color effect of the rainbow is not constant but at times (in a fog) appears almost white, while at other times only red and yellow are displayed. Its brilliance depends on the amount of sunlight. It has been reported that in Samoa sixteen simultaneous rainbows have been seen. From an airplane at a high altitude, a rainbow could appear to be a complete circle.

The most varied of nature's grand-scale color exhibitions in the sky are the polar lights—spectacles that are presented only in the region of the North and the South Pole. Those in the north are called "aurora borealis" and those in the south, "aurora australis." Comparatively few persons have seen either, but the northern lights have been seen by more than have those in the south. The accounts of scientific explorers and some paintings made on the spot give evidence that these effects are truly marvelous.

The fringes of the northern lights have been seen from many parts of this country, northern Europe, etc., where the displays take the form of arcs, rays, bands, curtains, draperies, coronas, and diffused glows. When faint, they are whitish; when brilliant, they are yellowish and have red, green, and other colored parts. In the arc type the lower part is red, the middle yellow, and the upper part green. The arc is usually accompanied by fanlike rays. The corona type, with its rapid changes of color, is perhaps the most beautiful. These phenomena are accompanied by a soft crackling sound, like rustling silk. The lights, which are closely connected with some disturbance on the sun, are accompanied by magnetic storms and heavy earth currents. Sunspots, some large enough to engulf the earth, seem to be responsible. The influence of the earth's magnetic poles on the electrical radiations from sunspots may account for the northern and southern polar lights. The original outburst, at any rate, is on the sun and what we see is only a reflex action. The lights are visible owing to the fact that the earth is a magnet surrounded by atmosphere. The electrical disturbances occur at an altitude of 100 miles or more. The green

of the lights is due to electrical bombardment on particles of oxygen and helium in the upper atmosphere.

Acknowledgment is given to the following sources of information. See also Part Seven.

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4

THE EARTH

A CONSIDERATION of every element and combination of elements on and in the earth would be a very large undertaking and will not be attempted here. But an explanation of the colors of a sufficient variety of matter will be attempted to help toward an understanding of the way in which all similar matter is colored.

Natural earth is found in one place or another in every color of the spectrum, in black, and in white. The coloration may be accounted for in different ways in different instances. Some of the contributing matters are listed here.

Red and Orange: Presence of iron oxide (hematite), chromium, lithium, manganese, laterite.
Yellow: Hydrous iron oxide (limonite), ferric oxide.
Green: Magnesium, iron silicate (chlorite), ferrous oxide, aluminum, magnesium, ferrous silicate.
Blue: Cobalt, zinc, aluminum, magnesium.
Violet: Cobalt, manganese.
Black: Carbon, magnetite, coal dust, vegetable matter.
White: Kaolin, quartz, feldspar, lead, steatite, asbestos.

Disintegrated and decomposed rocks add to the complex composition of some earths. Clays are colored in some instances black or dark gray by the presence of sulphide of iron (pyrite) or marcasite; blue, green, or gray by iron oxide (ferrous); red, brown, or yellow by iron oxide (ferric); white by decomposition of granite, kaolinite, white mica, quartz, porphyry, and syenite. Oxides of iron color the red clay found on the ocean floor. Calcium carbonate contributes to the color of the blue mud and, with more ocherous substances, to the red mud of the ocean floor. Green ocean mud is due to glauconite, spines of echini, and spicules of sponges. White comes from disintegrated coral, etc.

Pure water is in itself colorless and transparent. In spite of this, water can readily be represented by an artist with or without color. Because its density is greater than that of air, it bends

(refracts) the rays of light entering it from the air and distorts the vision according to the laws of physics. Water most frequently conveys some color impressions to the eye, as it reflects the light from its surface and from beneath the surface. Much water contains impurities or foreign matter, such as clays and vegetable and animal matter, which contribute to its appearance. If foreign matter is not too abundant, the water may reflect the apparent color of the sky or of surrounding objects. Quiet, clear water serves as a mirror, reflecting form and color with very little distortion. The writer has seen the Congo River when it had an orange hue and colored the ocean similarly for many miles around the vicinity of its mouth. The coloration is said to be due to countless numbers of fish eggs.

Far from land in good weather the ocean appears almost pure blue. Deep pure water, fresh or salt, appears blue; but upon disturbance the color changes to green. Temperature has no effect on the color of water. The presence of mineral, animal, and plant life (plankton) contributes to the green appearance of water; brown, red, and yellow can be due to brown algae and swarms of copepods; patches of olive green, to swarms of diatoms; milky white, to masses of other small life.

Beneath the surface of water, red can be distinguished as a color to a depth of about 150 feet; yellow, to 300 feet; green, blue, and violet, to about 600 feet. That is, light rays of such wave lengths can penetrate to such depths. Beyond about 600 feet no visible light is present. From there to a depth of about 3,000 feet are found rays of light of very short wave lengths. These are known as "actinic rays," by which chemical changes are produced, as in photography.

We are all familiar with red water running out of rusty pipes and green water in stagnant pools and possibly the yellow water from sulphur springs, but there is also luminous water. The light in this case arises from countless numbers of tiny animals found in sea water and, occasionally, in stagnant water inland. The animals emit a cold, greenish light, which when concentrated is sufficient to see by in the dark. The light is visible at night only and is increased by agitation. On a dark night at sea, great clouds of light are stirred up in the water by the ship's propeller and a

wake of light is left astern. At night the water is black and reflects the moonlight (if there is any) with great sharpness. A wave may appear deep blue in sunlight along its side, blending into darker and lighter green toward the crest, all as the result of reflection and absorption of various light rays. The wave is topped with a whitecap. The whitecap on a wave, the foam on a beach, and the "head" on a glass of beer are all caused by the same conditions: the tiny bubbles reflect almost all of the light rays and thus appear white. The white appearance is independent of the color of the liquid underneath. Soapsuds arising from even the dirtiest water are pure white. The bubbles present so many reflecting surfaces that from one angle or another rays of light of all wave lengths are scattered to the eye equally.

The iridescence, or rainbowlike play of colors, from soap bubbles or from other water surfaces is due to the presence of oil. The oil, which will not mix with water, forms a thin film on the surface. The film has a density different from that of water and is elastic. To blow bubbles would be impossible without this thin, elastic, oily skin. As the thickness of the film varies and changes with the movement of the water, these changes produce color changes. The film interferes with the light rays to the extent of bending them and separating those of various wave lengths before reflecting them to the eye. In addition to these conditions, the surfaces of soap bubbles are regularly curved and smooth, thus presenting more or less distorted reflections of surrounding objects and colors.

Steam, which is invisible water vapor, becomes visible when the vapor condenses again to water. Fogs and clouds are condensed water vapor; snow and ice are frozen water in different forms; ice is solid water, about as transparent as the liquid from which it is formed. Snow is a loose mass of water frozen into crystals. The crystals are formed in a great variety of shapes and sizes, but in general they are loose and feathery. As in the case of foam and froth, the particles offer a multitude of surfaces at every possible angle, from which the light is reflected. The mass is opaque, reflecting almost all the light that falls on it. If the snow is extensive, in sunlight it creates a glare that is blinding. In sunlight snow appears white; in moonlight, it varies in hue from violet to

yellow through green. Light from fire or other sources gives its own color to the surrounding snow; that is, it is reflected unchanged. Shaved or powdered ice appears white for the same reason as snow. An iceberg transmits and reflects the hues of sunrise or sunset when they are present in the sky near it.

Color in rocks is due largely to the minerals contained in them. Rocks, like earths and clays, are found in every color of the rainbow. Besides the content of the rock, its surface texture affects the color impression that it gives. A stone that appears gray when dry, may take on more definite color when it is wet or oily. When rocks were created, they may have had bright colors; but with the passage of time, the action of air, water, etc., has reduced most of them to a gray state. An old gray rock can be temporarily "rejuvenated" by exposure to concentrated violet and ultraviolet rays. Under such influences, drab stones show brilliant colors, according to their composition and the corresponding arrangement of molecules. Usually when this treatment is stopped the stone returns to its gray state at once, but in some instances it continues to glow for a short time afterward. It is known that this afterglow (phosphorescence), which may be due to minute particles of metallic impurities in the crystalline substance, can be quenched immediately by exposure to infrared rays. Rocks may have a greenish appearance caused by more or less minute forms of vegetation growing on the surface. Cut and polished stone presents coloration that is not visible in the rough form.

Basalt is a rock of volcanic origin which, when brown, derives its color from magnesia and iron; when green, from olivine; when black, from augite.

Obsidian, a glassy rock of volcanic origin, is chemically the same as granite, which occurs in black, gray, yellow, and brown.

Marble is a limestone that presents mixtures and patterns of all colors. When it is cut and polished, its luster is due to light's penetrating the surface a short distance and then being reflected from deep crystals. Some browns and yellows in marble are caused by iron oxide; reds, sometimes by withamite; blacks, by bituminous matter; whites, by wollastonite, tremolite, and feldspar; green, by green pyroxenes and amphiboles; brown, by garnet and vesuvianite; yellows, by epidote, chondrodite, and sphene.

There is a brown limestone that contains fossil shells and is iridescent. Much of the rock formations found in caves are closely related to marble. The larger formations, which appear white, are composed of calcium carbonate (white calcite). Some of the smaller forms, which are seldom more than 2 or 3 inches long and display a variety of pale colors, are of the quartz family. Among them are chalcedony, gibbsite, limonite, and opal. When these formations depend from the roof of the cave, they are called "stalactites"; when they extend upward from the floor of the cave, "stalagmites." Many hundreds of thousands of years have been required for forming them and their colors have in some instances been influenced by lava flows, gases, mineral solutions, etc.

Fire was formerly considered by science to be an element, along with earth, air, and water; more recently, however, it has been decided that none of these four are elements. Science now recognizes more than 90 substances as elements. An element is a substance that is not separable by chemical processes into other substances. Fire is a visible burning (combustion) resulting from the rapid chemical combination of a substance with (usually) oxygen. This rapid oxidation produces light and heat; but there are some slower forms of oxidation that produce no perceptible light or heat. The formation of rust on iron is a slow oxidation.

Flame is usually associated with fire, and our present concern is with the color of flames. Separate flames may appear blue, yellow, or red; but more often these three colors appear together in one flame. Flame often shows blue in the lower inside area, with a yellow area next, and red at the extremities. This may be accompanied by gray or brown smoke and, in the case of a candle, by a black column above the red tip of the flame. The gas that issues from burning matter, as it is heated, yields particles of carbon where oxygen is lacking. The blue area is produced when these particles of carbon get hot and start to burn without much air. A flame can be made all blue by allowing the air to mix with the gas before combustion. As the carbon particles reach the air, some of them burn brightly and cause the yellow light. Others are not consumed in the yellow area and, continuing outward and upward, glow redly with their slower combustion. Most of the particles linger long enough here to be consumed, but some of

them leave the flame without having been burned and continue to rise in the warm current of air. Such carbon particles form soot or lampblack. Carbon monoxide, a very poisonous gas formed by the incomplete combustion of carbon, burns with a blue flame. Carbon dioxide extinguishes flame. Burning sulphur produces a blue flame.

Smoke is a combination of gas, water, and carbon particles. Its color depends on the composition of the burning substance, reflected light, etc.

Phosphorus—a nonmetallic element of the nitrogen group that emits a greenish light visible in the dark—is poisonous and highly inflammable. The only element that changes color by compression, it turns from white to black under a pressure of 7 tons to the square inch. Various other substances glow with a greenish light in the dark. As has been previously noted, the glow in sea water is due to a species of small animals. Rotten fish and other flesh have at times been observed to luminesce. This is because of the action of bacteria. Wet decaying wood sometimes glows, owing to a variety of fungi. Since phosphorus is not known to be responsible for the light in these instances, their quality is called "bioluminescence" (emission of light from living matter). It may result from an oxidation of material made by the organisms.

All matter is believed to have the property of emitting light while exposed to the action of certain rays of the spectrum. This quality is not usually noticeable under ordinary illumination, but may be seen when exposed to ultraviolet rays in a dark room. Some matter continues to glow for a time after the source of the light has been removed. The appearance of cats' or other animals' eyes in the dark may be due to this quality or to bioluminescence.

Luminescence may be induced by radium, a metallic element that is found in uranium minerals. Radium is radioactive (capable of emitting spontaneous rays of material particles) and transmits this quality to nearly everything with which it comes in contact. Radium can be produced in the form of a white powder, but it is very scarce and very costly. It gives light and heat, glows like fire in the dark, and is said to lose only half of its power after sixteen hundred years, changing to lead after twenty thousand years.

Heat induces luminescence in metals, etc., and affects their color appearance. A piece of cold iron, which is bluish gray, becomes when sufficiently heated first red, then orange, then yellow, and finally white. As the iron cools, the color changes are reversed and it may appear violet after red before returning to its blue-gray state.

Within the blackness of the earth nature has created with a degree of frugality a variety of crystals, which have great latent beauty. This beauty is brought out to the fullest degree by cutting, polishing, and mounting the crystals. Men and women have always been fascinated by these miniature masterpieces of nature and consider them valuable in proportion to their scarcity and their color.

In the first class are diamonds, emeralds, rubies, and sapphires, which are called "precious stones." In the second class are the opal, topaz, spinel, aquamarine, chrysoberyl, peridot, zircon, tourmaline, amethyst, and moonstone, which are called "semi-precious stones." In commerce, diamonds are in a class by themselves, the others falling into the "fancy-stone" class. The characteristic crystal forms are destroyed in the cutting, but the cutting and polishing processes give the stone its sparkle. A few stones, such as the opal, are without crystalline form. All are very hard and the precious stones come clear. Color in a gem may be uniform or it may be arranged in layers, zones, or patches. The color of most gems is not an essential property of the mineral but is due to pigmentary matter.

Diamonds are pure carbon in crystallized form. Most other gems are of alumina or silica or a combination of these in various proportions, with or without other molecules. A diamond, the hardest substance known, can be cut only by another diamond. Although it cannot be scratched by a steel file, it can be crushed or split by a blow. It is the only gem with a luster of its own, a characteristic due to its hardness. This combination of hardness and luster is expressed in the adjective "adamantine." Pink, yellow, and black diamonds are found; but the so-called "blue white" stone, the most popular, while it is practically colorless, will, if properly cut, flash back all the colors of the rainbow. The color of other varieties is caused by various impurities. The diamond,

which is chemically identical with graphite and charcoal, can be converted into these forms by heat or electricity. It is found in single crystals, and the arrangement of its atoms is ascertained by X rays. Diamonds that have color can have it removed or changed by means of heating, but usually the stone regains the original color upon cooling. Pale yellow diamonds have been changed to bluish green by radium bromide. Whereas the genuine diamond is transparent under X rays, the "paste" product appears opaque. After exposure to sunlight or in the presence of radium, a diamond is luminous for a while in the dark. In ancient civilizations, stones were rounded and polished, but not cut with facets; diamond cutting to produce full brilliance was first achieved in the year 1746.

Next to the diamond in hardness is corundum (alumina), which, when pure, is colorless, but which is most frequently found combined with other mineral substances. It constitutes various gems, including the ruby and the sapphire. The red of the ruby may be due to the presence of chromium and the blue of the sapphire may be due to titanium. The sapphire occurs in either a transparent or a translucent form. A single sapphire crystal may, indeed, be clear in one part, yellow in another, and blue in another. The ruby possesses dichroism, being doubly refractive, so as to split the light falling on it into two rays, thus presenting two different colors when seen from two different points of view. There are some rubies and some sapphires in which the light forms a star-shaped figure, a phenomenon known as "asterism." This effect is the result of tubular cavities in the crystal, arranged at 60 degrees in planes perpendicular to its axis. Other arrangements of fibers produce cat's-eyes in chrysoberyl and quartz and tiger's-eyes in silicified crocidolite, which is lavender blue or leek green. The green of the emerald may be due to ferrous oxide or to structural properties that affect the light. An emerald is a variety of corundum or of beryl.

The opal, which does not occur in crystalline form, is a variety of silica having no particular shape and no distinctive color. Its distinction lies in its iridescence; for, as it is turned about, it reveals all the colors of the rainbow. Some varieties give out fire-like reflections when viewed in a bright light. The opal's appear-

ance results from accidental structural properties, which interfere with the light. The particles in the stone are arranged in equidistant layers and reflect light of short waves, while transmitting light of long waves.

The colors and sources of colors in some of the more valuable stones are as follows:

Agate: A semipellucid, uncrystallized variety of quartz. The least valuable.

Amethyst: A clear purple or bluish-violet variety of crystallized quartz. Pure silicic acid is the basic ingredient. An Oriental amethyst is purple corundum.

Aquamarine: A transparent bluish-green variety of beryl. Beryllium alumina silicate.

Beryl: Pink, yellow, green, greenish blue, greenish yellow, from silicate of beryllium and silicate of aluminum.

Bloodstone: Green chalcedony with red spots.

Chrysoberyl: Yellow or pale green, from aluminum, beryllium, and iron.

Diamond: Native crystallized carbon.

Emerald: From rich deep green to light grass green. A variety of beryl or corundum. Color due to chromium or ferrous oxide.

Garnet: The precious variety of this stone, deep red. Others, red, brown, yellow, black, violet red, green.

Pearl: Usually a pale bluish gray that is nearly white, but also found in various pinks, browns, and blacks. Occurs as an abnormal growth in some mollusks and has the quality of iridescence, resulting from its structure.

Jade: Green, white, brown, and gray, from silicate of calcium and magnesium.

Jet: A velvet-black mineral, of the nature of coal. Now replaced by artificially colored chalcedony and called "black onyx."

Lapis lazuli: Azure blue. A complex silicate, containing sulphur.

Moonstone: A translucent feldspar with a luster like a pearl or an opal. Its appearance is due to the layers in its construction.

Peridot: Olive-green variety of chrysolite; color from magnesium iron silicate.

Quartz (natural glass): Rock crystal, clear and transparent or with many variations. Granulated quartz is white sand, from which glass is manufactured.

Ruby: Red transparent corundum. Color due to chromium or minute quantities of other metallic oxides in the aluminum. A star ruby exhibits a six-rayed star.

Sapphire: Blue, yellow, green, orange, purple, pink, and other colored and colorless varieties of corundum. Color due to titanium or to minute quantities of other metallic oxides in the aluminum. The yellow variety is sometimes known as an "Oriental topaz." A star sapphire exhibits a six-rayed star.

Spinel: Various colors, from aluminum and magnesium. A spinel ruby is red.

Topaz: Crystalline quartz in various colors, from light yellow to deep orange and white, greenish, bluish, pink, rose, and red. The smoke topaz is ruddy brown. The Oriental topaz is a yellow sapphire. The yellow color is due to fluosilicate of aluminum.

Tourmaline: From a variety of minerals. From different groupings of molecules, it is found in many colors, including green, blue, brown, red, pink, olive, and black.

Turquoise: Blue, bluish green, greenish gray, from hydrous phosphate of aluminum and a little copper.

Zircon: Found colorless and in brown, red, gray, and yellow, from silicate of zirconium. The yellow stones can be changed to blue by heating. It is radioactive.

The colors of gems may change with the nature of light falling on them. Many sapphires appear darker under artificial light than in sunlight. The alexandrite, a variety of chrysoberyl, appears emerald green in sunlight but cherry red under artificial light. In some instances the color of stones may be changed by heating. The yellow topaz can be changed to pink. Zircons can be decolorized and made to resemble diamonds. The alteration in color brought about by light or heat is due to the displacement of the constituent atoms without derangement of their relative positions. The original color may be restored by exposure to ultraviolet rays or heat. The emanations from radium can impart color to the diamond, kunzite, and quartz. This change is probably due to the displacement of electrons within the atoms.

Amber: A yellowish, translucent, fossilized resin, which is often used as a gem, comes mainly from a mine near Palmmicken in Prussia, where it is dug out of a blue earth lying beneath about 50 feet of green sand.

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5

PLANT LIFE

THE COLORS of vegetation (flowers, fruits, vegetables, foliage, etc.) depend largely upon pigments. The coloring matter is manufactured in the plant by chemical processes. Following are the products of plant chemistry that contribute to the plant's color:

A. In cell sap and soluble in water.
   1. Anthocyanins are the source of red, blue, purple, and violet (depending on presence of acids or alkalies).
   2. Anthoxanthins, feeble source of yellow and orange.

B. In cells of fibers but not in sap. Not soluble in water but soluble in fat and oil.
   Plastids (units of specialized protoplasm in the cytoplasm).
   1. Xanthophyll, source of bright yellow.
   2. Carotene, usual source of orange. The substance which gives butter its natural yellow color and which is converted into vitamin A in the body.
   3. Chlorophyll, source of green, yellow, and orange.

These words come from the Greek language: *antho* (flower), *phyll* (leaf), *cyan* (blue), *xanthin*, (yellow), *chloro* (green).

Anthocyans and acid make a reddish color; anthocyans and alkali, a bluish color.

A red flower has acid in its sap, a blue flower has alkali, and a purple flower may have some or none of each. Thus the blue cornflower and the red cornflower have the same pigment, but one contains acid in its cell sap and the other contains alkali.

Vinegar is an acid. Urine contains uric acid. Lemons contain citric acid. Ants produce formic acid.

Soda, potash, ammonia, lime, etc., contain alkalies.

Litmus, a blue dyestuff derived from certain lichens is turned red by acids and restored to its original color by an alkali. White starch turns blue with red iodine.

The colorless jasmine turns bright yellow upon absorption of ammonia. Bluebells turn red when treated with formic acid. Blue

violets when crushed in vinegar turn red and when crushed in oil of tartar or potash turn green. A white flower may have "flower blue," yet lack something else that is necessary to produce color. Its opaque whiteness is due to the almost total reflection of light from many tiny cavities (vacuoles) in its cells, which contain air or clear fluid.

The color appearance of any plant results from the interference that white light experiences as it filters through the molecules of the chemical substances present in the plant cells. The substances absorb and reflect parts of the light as their molecular structure is altered by chemical changes.

Two white flowers that have been crossed may produce a purple flower, if each contributes what the other lacks.

Green flowers are rare in maturity, but buds and unripe fruits have much chlorophyll and often appear green. Leaves are usually green in maturity, although the young leaf bud commonly appears red and purple.

Anthocyanins (flower blues) are more abundant in the stem than in the leaf and on the under side of the leaf than on its upper side. The color of the stem results from a combination of the color factors of the leaf and the blossom. A stem may be brown from the chlorophyll in the green leaf, together with anthocyanins and acids in the red blossom. Color combinations frequently found in flowers are yellow and green, blue-violet and green, red-violet and green, with often a spot of yellow in the violet area. The color of flowers and leaves is usually more intense when it is seen by the light passing through them than by the light reflected from them. Depending on the surface texture of the plant, leaf, or flower and upon the angle of the incidence of the light, no color at all may be seen—only a flash of white light.

The meat of an apple may be white, but on exposure to the air it turns brown. When the apple is cut, it releases a substance called "tyrosin," which, when it is combined with oxygen, forms a dark pigment called "melanin." This is what gives the cut surface its brown color. Sunlight influences the development of chlorophyll. When a normally green plant is deprived of sunlight, it usually becomes pale and may turn white. Chlorophyll is responsible for the production of sugar and starch.

A freshly cut flower can be given any desired color if its stem is placed in water containing a dye of that color. The dye is drawn up through the stem with the water and deposited among the cells of the petals. Florists color white carnations a bright green in this way, for sale on St. Patrick's Day.

Vegetation may become phosphorescent, may give off a weird greenish glow in the dark. As this condition is due to bacteria or fungi, such vegetation is usually decaying. Bacteria are remarkable vegetable microorganisms, which can be either very useful or very harmful.

Flowers appear in white and in every conceivable single color (with a minimum of black and green), as well as in thousands of color combinations. Many color variations are found even within the same family. Nature has provided a flower to suit anyone's taste, but not all flowers are found everywhere. The names and predominant colors of some of the more common flowers produced in this country follow.

Azalea austrina: Brilliant yellow and orange.
Begonia (wax plant): Pink, white, scarlet, orange, apricot, yellow, terra cotta.
Bleeding heart: Slender sprays of pink heart-shaped bangles.
Bottle brush: Red and yellow.
Buddleia: Purple clusters.
Calendula (marigold): Orange, yellow, cream.
Calla lily: White, yellow.
Calliopsis: Yellow, crimson, brown.
Camellia: Cream, pink, red.
Campanula: Purple, violet, mauve, pink, white.
Canna: Red, crimson, pink, orange, yellow.
Carnation: Red, pink, buff, white.
Cornflower: White, pink, red, blue.
Chrysanthemum: Red, white, yellow, brown, mauve.
Clematis: Purple, violet, sky blue, white.
Columbine: Yellow, orange, violet, pink, blue, white.
Coreopsis: Golden yellow.
Crab-apple blossoms: Various pinks.
Crocus: Golden yellow, lavender, deep blue, purple, white.
Dahlia: Yellow, orange, red, pink, mauve.
Daisy, English: Pink, white (having a dense cluster of petals).

Daisy, Michaelmas: Purple, blue, mauve, orange-red, with yellow center.
Daisy, oxeye: White with yellow center.
Delphinium (larkspur): Light blue.
Dogwood: Pink, white.
Doronicum: Brilliant yellow with orange center.
Erigeron (fleabane): Blue, white, lavender, mauve, with yellow center.
Flame vine: Brilliant orange clusters.
Forget-me-not: Blue.
Forsythia (golden bells): Brilliant yellow.
Fuchsia: Purple and crimson, pink and white.
Gentian: Vivid blue.
Geranium: Pink, white, red.
Gladiolus: Pink, gold, orange, crimson, scarlet, white, deep violet.
Hemerocallis (day lily): Yellow and orange.
Hibiscus: Crimson, orange, rose, golden apricot, cream.
Holly: Bright-red berries with dark-green leaves.
Hollyhock: Yellow, pink.
Hyacinth: Blue, blue-violet, pink.
Hydrangea: Pink, white, blue. (Normally pink flowers can be turned blue by making soil acid with alum or iron filings.)
Iris: Yellow, violet, mauve, light blue, golden.
Kalmia (mountain laurel): Pink clusters.
Larkspur: Pink, blue.
Lilac: White, violet, pinkish lavender, dark purple-red.
Lilies: Yellow, orange, red-orange, white, pink.
Lobelia: Vivid blue.
Lupines: White, pink, blue.
Magnolia: Creamy white, purple, pink.
Mallow: Pink, red.
Marigold: Golden yellow, orange, brown.
Morning-glory: Pink, blue.
Narcissus (daffodil): White with yellow center, yellow, white and yellow.
Nasturtium: Yellow, white, pink, red.
Oleander: Pink, white, red.
Pansy: Yellow, violet, brown, blue, and other colors with white and yellow and other centers.
Peony: White and golden yellow, pink, red.
Petunia: Pink, blue.
Phlox: Pink, red, light blue, light purple.
Physalis (Chinese-lantern plant): Clusters of bright orange with green stems, blazing scarlet.

Poinsettia: Blazing scarlet and dark-green leaves.
Poppy: White, golden yellow, orange, scarlet, apricot, mahogany, salmon, pink.
Primrose: Yellow.
Rhododendron: White, pink, crimson.
Rose: White, red, yellow, pink, cream.
Rudbeckia (black-eyed Susan): Yellow with brown center.
Snapdragon: Pink, orange-yellow, orange-red.
Strawflower: White, pink, yellow, red.
Sunflower: Yellow with brown center.
Sweet peas: White, pink, red, red-orange, lavender.
Tulip: Yellow, orange, red, pink, blue, violet, purple, and various combinations.
Verbena: Clusters of white, vivid blue, pink, orange-red, light purple.
Violet: Many tints and shades of blue and violet.
Water lily: Vivid rose, red, crimson, apricot, yellow, white, light blue.
Wisteria: Light purple.
Zinnia: Pink, scarlet, orange, golden yellow, rose, salmon.

Acknowledgment is given to the following sources of information. See also Part Seven.

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6

ANIMAL LIFE

The colors displayed by insects, fish, birds, beasts, and human beings have either one or both of two causes: (1) the presence of color-forming chemical matter in or among the cells (pigment) and (2) the structure and arrangement of surface tissues. That is, a body can convey a sensation of color either because it has pigment deposited on or near its surface or because it has a surface which is devoid of pigment but which breaks up the light irregularly, or because of both conditions.

Most of the pigments of animals are definite organic compounds formed within the tissues of the living body, which is a chemical laboratory. In a few instances, pigments are introduced by food and deposited among the cells, without chemical change. With this exception, animal colors depend on the presence and interaction in the tissues of colorless color bases, chromogens, and ferments or enzymes which, acting on the color bases, yield colored products. Some of these coloring matters (pigments) are

Cytochrome. Found in all living matter, this pigment is almost colorless in itself. One of its functions is to control the distribution of oxygen.

Lipochromes. These are known as "fat pigments" and are soluble in fats or solvents of fats. They are of two kinds: (1) those which form a compound with caustic alkali, and (2) those which do not form a compound with caustic alkali. The latter are found in both plants and animals. Lipochromes are principally responsible for the reds and yellows. If to this dried pigment is added nitric or sulphuric acid, it turns blue.

Melanin. A granulated pigment, melanin is responsible mainly for black, brown, and gray tones. It is closely allied to haemoglobin and the hormone adrenalin (which turns dark on exposure to air) and tyrosin (a protein product). Melanin may be due to the disintegration and/or decomposition of haemoglobin.

Haemoglobin. This is a compound in the blood containing carbon and iron (red). In some invertebrates the compound contains copper instead of iron and effects a blue color.

Pigments formed from waste products:
Lepidotic acid (modified uric acid). Yellow.
Guaninin (modified uric acid). Various colors.
Flavonol. Yellow and other colors.
Introduced pigments:
Carotene. Yellow and orange.
Chlorophyll. Green.

Many of these names come from Greek roots such as: *lipo* (fat); *chroma* (color); *cyto* (cell); *mela* (black); *gene* (birth); *zoo* (animal); *haem* (blood); *chloro* (light green); *phyll* (leaf).

The color of an animal—one of its most unstable qualities—may vary or change with age, environment, temperature, rainfall, season, sex, diet, mood, and other influences.

Red (and Orange)

This color is very common in all forms of animal life. Except in rare instances, it is due solely to pigment and reaches its greatest brilliance in deep-sea life. It may result from

Lipochromes. These pigments are present in the red Norway lobster and in the red wattle of grouse, etc. The ordinary lobster has normally a bluish appearance, which is due to protein and copper in its blood; but on cooking, the lobster turns red because the heat destroys the protein and frees the lipochromes.

Haemoglobin. This contributes to the color of human skin, etc.

Uric-acid pigments. These are carmine of cochineal, etc.

Yellow

This is a color that is common. It results from

Lipochromes (principal source).
Uric-acid pigments.
Diluted melanin.
Weak haemoglobin.

Carotene. Derived from plant food, this pigment is found in egg yolk, beak and legs of fowls, and butter. Carotene, a vegetable-fat pigment found in various plants, is especially abundant in carrots, whence the name. It is soluble only in fats and accumulates where fat is.

The yolk of a hen's egg may be artificially colored by the inclusion of a dye in her food.

Algae (water-plant life) growing on the surface. The bottom of the sulphur-bottom whale is normally white, but it becomes sulphur yellow in feeding grounds, owing to attachments of algae.

Blue (and Purple)

This color is rare among the higher forms of life, but quite common in the lower. It may be due to

Melanin (diluted).

Haemoglobin and by-products.

Uric-acid pigments. These are pigments such as cause the purplish blue of some mollusks. The color is generally due to surface structure with or without the aid of pigments. The blue may be accompanied by iridescence or not, according to the circumstances causing it. The blue of bird feathers is usually due to surface structure but the blue of birds' eggs is due to pigment (from haemoglobin).

Green

Green, which is the rarest of animal colors, may be due to

Presence of parasitic growths (algae) that contain chlorophyll.
Self-made chlorophyll, as in some protozoa and other minute "animals." Some of these are not really animals but are actually motile plants.
Bonellein and similar green pigments produced by some worms (gephyrean and palolo worm, etc.).
Introduced chlorophyll, as in case of some caterpillars and certain oysters.
Surface structure alone or with pigment.

Iridescence

All the colors of the rainbow are exhibited in many forms of animal life. These iridescent colors, which are to a great extent the result of surface structure, shift and change with the movements of the animal.

Black (Brown and Gray)

This color, which is very common among higher forms of life and insects, is rare in mollusks and crustaceans and is not

common in the lower animals. Such coloring is due almost entirely to melanins in various conditions and combinations.

White

White is present in nearly all forms of life. It is caused primarily by a lack of pigment but may also be due to

A powdery or chalklike surface.
Gas vacuoles, which are bubbles of air in and among colorless cells, in the spaces usually occupied by pigments. Either of these conditions results in a nearly total reflection of light, as in the case of foam.

The lack of pigment may be due to

Absence of chromogens and/or enzymes.
Presence of something that checks these.
Presence of minute organisms that eat the pigment.

The theory of these organisms according to the bacteriologist Metchnikoff follows.

In the blood and tissues of animals are minute living bodies whose function is to rid the body of invading microbes and to heal mechanical injuries. Collectively they are called "phagocytes" (eater cells). The smaller are known as "microphags" and the larger as "macrophags." In the performance of their duties they seem to require nourishment and are partial to pigments. Apparently the busier they are the more they consume and the less able is the body to restore what they have removed. This seems to link pigment with health. The microphags confine their activities to the blood stream, while the macrophags work and eat in the tissues. These latter consume the pigment in the hair first and then turn to that in the skin.

The coloration of some creatures may help them to exist. Such protective coloration tends to conceal them from their enemies. Coloration may be permanent or may change with the seasons or with the moment. Some creatures that are disagreeable, dangerous, poisonous, unpalatable, or otherwise undesirable as companions or as food are often conspicuous by their coloring, perhaps to warn their fellow beings. The production of pigment in all forms of life

is often closely associated with sexual activity. Coloration is not confined to the surface of living things. Some body cavities are black; some bones are green; blood may be red, gall green, egg yolks yellow; and the brain and the spine contain pigments, except in albinos.

Albinos occur in all forms of life. There are albino animals, fish, birds, reptiles, and plants, as well as human beings. The albino's system may develop a small amount of yellow pigment, but it does not produce melanin. In the true albino all pigments are absent. This results in white hair over the whole body, a very fair skin, and pink eyes. The pink of the albino's eyes is the blood of the retina visible through the transparent tissues of the iris. As there is no pigment (melanin) in the iris, the retina is very sensitive to light and weak sight results. Albino rabbits and mice are quite common. Albino frogs are rare. "White Indians" have been reported by travelers in certain regions; these may or may not be albinos. The writer has seen albino Negroes in Africa whose eyes, hair, and skin were pink. Others have been seen whose skin was mottled by light-brown and white patches. Examples of such abnormal pigmentation are sometimes displayed in circus side shows, where they are called "leopard people."

Most forms of life appear darker on the upper side and lighter on the lower side. Whatever the cause or purpose of this condition, the effect is in part to render the creature less visible in a strong light.

If you were to examine almost any bird feather under a microscope, you would observe the surface to be very irregular. The irregularities would vary between the feathers of one bird and those of another. In one instance the surface might be scaly, in another hairy, etc. These minute outgrowths greatly influence the apparent color of the mass. The brilliant colors of the peacock are largely due to the surface structure of the feathers. However, were it not for the presence of some pigment, the feathers would appear practically white, as in the case of the white peacock. The feathers of the white peacock when they are seen in certain positions show the "eyes" and other markings that characterize the more common bird, but because they lack all pigment, the appearance is reduced to a pearly whiteness.

A large quantity of melanin is responsible for the blackness of

the crow's feathers. A feather that owes its color to surface structure alone reveals no color when it is viewed against the light. Scientists declare that there is no blue pigment in bird feathers, but that the sensation of blue is always largely due to surface structure. Likewise, the green of parrots and of other birds is not caused by any green pigment but by surface structure, together with some melanin and yellow pigment. Melanin is pigment that can be separated from the body in which it is deposited. One bird whose color is due to pigment is the touraco of Africa. It is a large bird like a parrot and has bright-red feathers with green spots. A story is told about a hunter who caught one of these birds after a heavy rain, when the bird was soaking wet and could not fly away. After handling it, the hunter noticed that his hands and clothing were stained red as if by blood. The bird was not wounded or bleeding, so the conclusion reached was that the color was due to a dye released by the wet feathers. It was found later that no amount of washing would remove the red stain from the hunter's clothing. Man being the curious animal that he is, attempts were made afterward to get more of this red dye from other touracos, both alive and dead, by soaking them in water and squeezing the feathers, but nothing happened. Since no dye was procured, it was assumed that the hunter had been just "spinning a yarn." However, several years later, when someone found that rainwater dripping from leaves contains ammonia, the case of the touraco was again brought up. Ammonia was added to the water and touraco feathers were then soaked in it. This time the feathers yielded the red dye, which is called "turacin" and is very durable in certain fabrics.

Diet may or may not influence the coloration of birds in general, but in some instances a change in food has brought about a change in color. A bullfinch, which normally has a red breast and throat, if it is fed on hemp seed turns solid black. Some Amazon parrots will change from green to yellow when fed on the fat of certain fishes. Some yellow canaries have been changed to orange when cayenne pepper was introduced in their food, and this affected the color of the young birds also, since they obtained their food from the parent birds, who had predigested it. In this instance the red color was due to a pigment called "capsicin" in the pepper, which

was conveyed to the tissues by a fatty substance called "triolein." When carmine was put into the food of yellow canaries, the yellow disappeared and they became white. Natives on the Amazon River have pulled feathers from parts of the green parrot and rubbed the exposed skin with a live frog or with a poison procured from frogs or salamanders. After this treatment the feathers of the new growth are yellow instead of green. White blackbirds are not uncommon, but why such irregularity is more frequent in the case of this species than it is among others is not known.

The color of birds' eggs depends upon pigment. The color may be due to melanin, lipochromes, or some derivatives of blood pigment. As regards brown and white hens' eggs, the scientist says, "Birds in which the gene of major importance is in a homozygous condition, lay eggs with brown shells." It may be said that brown shells result from a certain predominance of pure racial characteristics. No expert has ever been able to detect the slightest difference in flavor, quality, or richness between a white- and a brown-shelled egg.

The present brilliant coloration of birds is assumed to be the result of extensive permutations (series of changes) from the primitive. It is known that every animal climbs its own ancestral tree in the course of its life history. Human beings finish the climb before birth, but many other forms continue to climb after birth. Much of this after-birth climbing has to do with the matter of color. Young birds having colorful parents often arrive in the world with dull-gray coloring and sometimes with spots and stripes quite different from those of the parents. Such markings are believed to have been common to the ancestors of the species. Environment and many other factors may have contributed through the ages to bring about the present appearance of the adult bird. At any rate, the young one loses little time in discarding his ancestral robes for the current mode.

Coloration varies in a single family. Over 100 different color combinations have been found among swallows, yet these vari-colored birds belong to one family because their skeletons are alike. Likewise, over 150 different color combinations have been noted in the kingfisher family. Indeed, such variation is common in many of the bird families.

As has been mentioned before, sex and sexual activity have much to do with bird coloration. The pigment-stimulating hormones initiate and sustain the development of color in plumage. The female frequently displays comparatively dull colors and is thus less visible as she hovers over the eggs in her nest. The young male bird, after discarding the ancestral colors, takes on colors similar to those of his mother. This may afford him, too, some protection. But as he matures, he drops the drab of his mother for the brilliance of his father. If the ovaries of a hen pheasant become diseased, she assumes the dress of the cock; and this occurs to some extent with advancing age, as well. On the other hand, some birds—parrots, jays, and kingfishers, for instance—have brilliant plumage in both sexes and at all ages.

Color may change with the season. In the winter the scarlet tanager (male) is green, with black tail and wings, but in the summer the green changes to a vivid scarlet. The color of the female of this family is a dull green in the winter and orange in the summer. The bluish hue of bare areas on birds' skin, such as the neck, wattles, and head, is due not to any blue pigment, but to the structure of the skin plus a small amount of melanin. This bluish skin color often fades after death, as does the pink color on the breast feathers of some birds.

The pastel tints of some birds are in part the effect of powdered plumage. Some birds, such as many pigeons, herons, hawks, and parrots, produce a powder, which they distribute over their feathers. In some instances the powder comes from single feathers located on various parts of the body. Some birds that appear pale elsewhere become black in a humid country.

Although much observation has been devoted to the coloration of birds and many volumes have been written about it, there are still many unsolved mysteries connected with it. The subject offers much food for thought and an invitation to study.

Life is more abundant and varied in the water than on the land. The largest and the smallest forms of life are there, and among water creatures are found the most brilliant colors. For every curiosity on land or in the air, there are dozens in the water. Man has gone but a short distance beneath the surface of the sea; he may be able to reach Mars before he gets to the bottom of oceans

here on earth. He has an intimate knowledge of many very distant planets, but only vague ideas and little positive knowledge about life and conditions in the deep waters of these oceans. Many persons have looked around in the fairyland a few feet below the surface of quiet waters with the aid of a helmet or of goggles or through the glass bottom of a boat, but few have gone further than this. It was the writer's pleasure once to meet Dr. William Beebe and inspect his workshop on Nonsuch Island in Bermuda. Much of what knowledge we have of marine life is due to Dr. Beebe's efforts and to his explorations in the sea.

The coloration of fish from birth to maturity follows a definite sequence, according to the sumptuary laws of the species. Many sea creatures are colorless and transparent. In some, pigmentation starts from within. In the larval stages, some species would be invisible except for their black eyes. One species of catfish is transparent even in maturity, its entire skeleton back of the head being clearly visible through its transparent skin and flesh. This fish, which is found in the Amazon River, is quite small. Fish scales are usually glassy, colorless, and transparent, while a few are white and iridescent.

The upper side of a fish is darker than the lower side. This counteracts the light from above and tends to produce a uniform appearance that makes the fish less conspicuous. In general, ocean fish are most frequently blue above and white below. Fish that live deep in the sea are usually blackish and many have luminous organs; fish living among shallows and weeds are often greenish; those that skim the surface are usually silvery; and those living in coral formations exhibit patches of color. The colors and patterns may help to make the fish less visible in its surroundings and may help to delay its extermination until it has had a chance to reproduce its kind or has developed into a suitable meal for some other fish. Water life is very abundant and very precarious. Almost all fish eat other fish and their life is a savage, bloodthirsty merry-go-round.

This keen battle for life in the water has developed extra protective powers in many species of fish, although its ultimate effectiveness is questionable. Such fish have the power to change their colors and patterns of colors at will. It has been found that

they can change yellows and browns rapidly and reds, greens, and blues more slowly. The osbeck, a fish of Bermuda, can change from red to white in from 4 to 8 seconds. The change back to red takes from 16 to 22 seconds. Granules of pigment are distributed in pigment cells of the skin, which are called "chromatophores" and effect color changes as their sizes and shapes are changed. These changes are controlled by the nervous system of the fish. The fish's nerves are stimulated by what it sees. The scales and outer skin of such a fish are transparent. The chromatophores are star-shaped, connecting bodies forming a network, in which the pigment granules are arranged in layers. In addition to the pigment cells, there are reflector cells (iridiocytes), which reflect the light in various wave lengths depending on the setting of the reflector. By contracting and expanding the pigment cells and adjusting the reflector cells, the fish is able in a very short time to match the colors and designs behind it.

Some fish appear to effect rapid color changes for pleasure rather than for any protective purpose. Usually their environment is colorful and the effort seems to be directed not at matching any particular color or pattern but at vying with the surroundings in variety. The Nassau grouper can change from its generally plumbeous hue through variations to a uniform creamy white. These changes are effected by the fish apparently because the exercise gives it pleasure. It changes color as an athlete might flex his muscles, from the exuberance of his spirit and the joy of being alive. Such fish when placed in a tank or some other uncolorful environment continue to change colors. The changes, although various, are constant and reappear in the same way in the same combinations, yet no two fishes display the same hues at the same time under the same conditions. Flat fish, which are accustomed to lie on the bottom, seem to melt into the background and become quite invisible. Various Malay fighting fish change to brilliant hues under stress of emotion. Blind fish make no response to light or environment and remain a uniform color. Death in many cases fixes the color and pattern last displayed by a fish, but in other cases the fish loses its color after death.

The power of changing color at will is possessed by only a few other forms of life, although in various animals, including human

beings, rapid color changes are brought about from causes beyond their control.

From Germany comes a fish, called the "elritze," that provides a remarkable test for cancer. A sample of the suspected patient's blood is prepared and injected into this fish, which is normally a silver-brown color; if any cancer hormones are present in the injected fluid, the fish immediately turns red, remaining so for about 5 minutes, after which it returns to normal and can be used for another test.

Sponges grow in every color, but the average live sponge is usually dark brown. Hands that handle it are stained the same color by the iodine manufactured in the sponge.

The pearly or iridescent luster of the scales and skin of some fish is due to a pigment known as "guaninin," which is formed from waste products, such as urine. The red flesh of salmon is due to lipochromes in its fat. After a long fast, when the fat has been consumed, the flesh becomes pallid. The pigment melanin is responsible for most of the blacks and browns and also for the "ink" of the cuttlefish. The reds of most crustaceans result from lipochromes. The blues of some mollusks and crustaceans are caused in part by haemocyanin. Yellows and greens are often the result of animal or vegetable parasites.

At birth the ordinary prawn is colorless, with the possibility of becoming any color. The eventual color is determined by chance. Newly born prawns, struggling about in their element, attach themselves to the first weed or rock on which they can take hold, and being in a susceptible stage, they develop the color of the anchorage. Once this color has been acquired, it remains with them for life. Apparently it is to serve as a protection, for thereafter in their wanderings they always seek an environment that is in harmony with their established color. The Aesop prawn, however, has the power to change its color, assuming the color of its environment by day, as a rule, but changing to pale blue at night or when it is placed on a white background by day. This change of color is brought about by pigment distribution, which is controlled by the nervous system. The pale-blue effect is achieved by the concentration of the pigment granules in small balls and the releasing of some other substance into the body fluids. Upon the

introduction of daylight or removal of the white background, the creature withdraws that substance from the body fluids and redistributes its pigments as the surroundings dictate.

Some crabs plant growths on their backs or else hold anemones, sponges, pebbles, etc., on their backs, in an attempt to make themselves less noticeable. In France it is a practice to fatten certain oysters in tanks of water containing large amounts of cobalt-blue diatoms. As the oysters assimilate the diatoms their gills become bluish green; therefore, they are known as "green" oysters and are considered to be a food delicacy.

There is a species of eyeless fish living in underground streams in some caves of Cuba (and elsewhere) that is white all over. From great depths in the ocean where sunlight does not penetrate, Dr. Beebe procured specimens of other queer fish that were all black. At the same time, smaller specimens drawn out of this same ocean darkness displayed brilliant crimson and other hues. A common quality of life from the ocean depths is bioluminescence (light emitting). This light, the cause of which is not known, may result from different factors in different cases. It is known that some crustaceans emit flashes of light after having eaten luminous organisms, and in such instances the excrement of the creature is luminous, also. The color of the emitted light varies with the nature of the fish. Jellyfish emit a greenish-golden light, which arises from epithelial cells; the giant pyrosoma, when touched or agitated, gives out a bright bluish light; the Portuguese man-of-war lights up like a fire balloon at night. The light of certain mollusks arises from ganglion cells of the nervous system. A variety of deep-sea prawns excrete clouds of blue light. Some deep-sea crabs carry luminous anemones on their backs. While the function of all this illumination is not known, it is possible that in some cases the light may attract other creatures that are desired for food.

Certain denizens of the deep display rows of lights along their sides or clusters elsewhere. One specimen was noted to have over 250 of these lights. Others carry "lanterns" at the end of rods that project from their heads. As Ripley would say, "believe it or not," one is equipped with a lantern, a rod, a line, and hooks. This fish, which is itself a fisher for fish, is no figment of a dream, but a very

material actuality; at this very time such animals are going about their business in the dark depths of the oceans.

Another odd specimen carries port and starboard lights. This creature has two bright plates, one under each eye, one showing a red light and the other a green light. Such creatures, fantastic though they may seem, are nevertheless quite real. Dr. Beebe and other scientists have procured specimens of them from great depths, in nets, and have been able in some instances to keep them alive for a while, during which time scientific observations have been made of them and skilled artists have recorded their colors in paintings. Afterward, the dead specimens are preserved and kept in sealed glass containers, and sometimes replicas are made for distribution to museums.

Among rare fish is a small species called "neon tetra," which is about an inch long and has iridescent blue, green, and yellow stripes extending the length of its body, resembling a miniature neon sign. It comes from Brazil. Another rare fish is the chichlasoma kongo from Guatemala. The female of this species displays brighter colors than the male—a circumstance that is very rare indeed among fish.

Some reptiles also have the power of changing their colors at will. The chameleon is one of these. Through its transparent, rough, and scaly skin it can produce many colors, separately or in combinations. The machinery effecting these changes is similar to that in fishes that have the same faculty. The pigment of the chameleon is arranged in two layers of cells in the dermis, the outer layer contributing to the yellowish effects and the inner layer to the reds, blues, etc. The chameleon is a slow-moving, methodical creature and apparently makes its color adjustments mainly to match its environment, in order to become less conspicuous. It can match almost any background on which it is placed. In contrast with the creature's extremely slow movements, the color changes are effected fairly quickly and its tongue darts out with great speed to catch unwary insects. Some other lizards that can change colors run rapidly and jerk their heads up and down with much energy. Many of these seem to change color for the fun of it. Their actions are closely related to their emotions. In frogs that change color, the pigment is arranged at different

levels, some being in the dermis and some in the epidermis. The pigment in any case is contained in a branching network of cells, which can be contracted and expanded at will. The contraction of pigment into small, compact balls leads to a loss of color and its expansion to a display of color. This action can be influenced by light or shade, presence or absence of moisture, temperature, mood, and other conditions. In the case of frogs and similar creatures, the changes are controlled by hormones (substances passed into the system by various glands, such as pituitary, thyroid, and sex glands), which in turn act on the cells. In the case of the albino frog, there is little or no absence of pigment, but a condition exists wherein the necessary hormones are not being secreted by the glands and the frog is without the power to release the pigment globules.

Most reptiles have no such kaleidoscopic abilities and are required to go through life with but one set of colors. No color is especially common or uncommon among them, but representatives of one species usually assume the same colors and combinations. In the majority of instances the coloration is brilliant. It may be that some of the vivid contrasts displayed are for warning, attraction, protection, or other purposes. The Gila monster, a poisonous lizard, is black and red. One poison frog has a dull back but a red-and-black belly, which it exhibits as a warning to an approaching enemy. Others are black and white, black and red, or black and yellow, as are some salamanders.

As is true of birds and fish, the principal distinguishing feature between two groups of animals of the same family is often their color. The cat belongs to a large family all of which have similar skeletons, but which are more readily distinguished one from the other by the quality, quantity, and markings of their hair. The dog belongs to another large family, the cow to another, the horse to another, etc. As is true in the case of birds, all animals climb their family tree in the course of their development. In coloration and markings, the young animal may look quite different from its parents. Its appearance is supposed to resemble that of its ancestors. As the animal matures, it takes on a resemblance to its parents. The parents contribute the factors that determine the coloration of their offspring, and no fur-bearing animal is

able to change colors at will, although changes do occur in orderly sequence according to age, sex, season, etc.

The apparent colors are in most instances due to the distribution of melanin and lipochromes. According to its concentration, melanin effects various blues, grays, blacks, and browns. The lipochromes account principally for the yellows and reds. White is effected by an absence of pigment and the presence of air bubbles in the hair. Just what factors regulate the distribution of pigment in the individual hairs to effect patterns, such as spots and stripes, is not known. Under certain light conditions, spots can be perceived on the solidly black leopard, just as "eyes" can be discerned in the feathers of the albino peacock. Wild cattle are usually of one color, whereas domestic cattle are seldom of one color but most often display vivid contrasts. Animals that live in forests are frequently spotted, while those that spend most of their time among tall grasses are more often striped. Those belonging to the desert and short-grass regions are usually of solid colors and, if they show any variation in tone, are all darker above than below. Light and temperature may have contributed to the development of color as is suggested by the prevalence of white in the cold regions and of dark hues in the tropics. However, neither black nor white is absent in any climate. Diet probably has little to do with animal colors. It is known that red madder will be deposited in the bones of pigs when it has been included in their food. Some coloration may serve as a warning. The skunk is black with a vividly contrasting stripe of white down its back. The liquid that this animal can spray at will is so powerful that it can induce fainting, can make dogs and other animals foam at the mouth, and can cause blindness.

The slow-moving sloth often has a greenish hue, which is due to minute vegetable growths on its hair. Mice are grown in all the following colors: black, white, red, brown, blue, cream, black and tan, fawn, lilac, champagne.

A species of South African mole has iridescent hairs distributed about in its fur, the iridescence being the result of the peculiar surface structure of those particular hairs. The fantastic coloring of the face of the mandrill is said to be due more to the nature of the skin than to any coloring matter.

A certain African bat (*Megaderma frons*) makes the upper surface of its body yellow by distributing on it a powder, which it manufactures and stores in a "powder box" in the lower part of its back.

By far the most numerous creatures among those that inhabit this earth are the ones without backbones. They are called "invertebrates." Of these, the insects comprise many interesting and important families and display a great variety of shapes, sizes, and colors.

Butterflies—perhaps the most colorful of the insects—exhibit all the colors that we can see and some that we cannot perceive. Iridescence is common in many of the insect families, such as butterflies and beetles. This quality of showing metallic and rainbow effects is, as in other instances, due to surface structure. Under the microscope, a butterfly's wing reveals that its surface is covered with clusters of minute scales, which vary in shape, size, etc. These colorless scales, together with various pigments, produce all the colors. Mammals secrete uric acid, but many insects convert it into pigment. Lepidotic acid and flavonol, which are uric acid derivatives, contribute to the yellows in the wings of some white butterflies and moths. The coloration of certain moths can be changed by diet, and some caterpillars owe much of their color to the food that they eat. The color of a silkworm's cocoon is the same as that of its prolegs, and they may be silvery white, cream, yellow, lemon, or green. A few insects have the power to emit light. What it is that they produce to make the light is not exactly known. The eggs and larvae of such insects are luminous. The light comes from layers of cells beneath the skin of the insect's abdomen. The designs on butterfly wings are quite symmetrical, with the upper and lower surfaces usually different from each other. This seems to afford some protection to the kalluna butterfly of India. The outer surface of its wings is dark purple and orange, which make it conspicuous while in flight; but when it settles on a bush and folds its wings, it becomes almost invisible. The wings are shaped like a leaf and the under surface is dull, so that when it is at rest it looks like a dead leaf. To complete the illusion, each of this insect's wings is marked with a midrib, has black spots resembling fungoid growths, and possesses transparent windows, which resemble holes. As if this were

not enough, the insect draws its head and antennae between its wings.

Moths do not fold their wings upward, as butterflies do, but draw them in to the body when at rest. The larger, outer, wing, which is usually dull, covers the secondary ones, which are frequently of bright colors. It is possible that the coloring of some insects serves as a warning. Such may be the case with wasps, hornets, and bees, which can severely punish their annoyers. It may also be true of certain unpalatable caterpillars and spiders. One peculiar little creature manages to escape early extinction by imitating to perfection a bird dropping. We are all familiar with numerous insects that bear a remarkable resemblance to leaves and twigs.

Insects do not necessarily see each other as we see them. The optical machinery of an insect is radically different from that of a mammal, a reptile, a bird, or a fish. The insect has clusters—sometimes many thousands—of eyes, which are stationary. With the apparatus it can see colors beyond the violet, which we cannot perceive. On the other hand, red to an insect is just a dark gray. Some flowers and parts of flowers reflect ultraviolet rays and some do not. Our eyes are unable to detect this, but the eyes of insects can. To us three portulacas appear separately red, yellow, and pink. The insect does not get any of these sensations. Instead, it gets from all three flowers a strong uniform sensation from the ultraviolet rays reflected. Three zinnias likewise appear to us the same red, yellow, and pink. These flowers reflect very little ultraviolet and the insect gets a weak, uniform sensation from all three zinnias. The petals of yellow black-eyed Susans appear to us to be of uniform color, but to the insect there is a strong contrast in color between the tips and the bases of these petals.[1]

Man may be classified according to color. He is either white, yellow, red, brown, or black. Except for the albino and a few accidental cases, all men have the same color bases. The apparent color depends on the proportion of each pigment present. Although a "white" man may appear every color of the rainbow under certain conditions, he is unable to change his color at will. Man has several layers of skin, which are considered in two parts — the

[1] Lutz, Frank E. "Field Book of Insects," G. P. Putnam's Sons, New York, 1935.

dermis and the epidermis. The dermis (corium) is composed of two layers of living tissue lying beneath the epidermis. There is no pigment in this layer of any man's skin. The epidermis (cuticle) lies on the outside and is composed of five layers. Only the Negro has any pigment in the epidermis, and that lies deep in the fourth and fifth layers. In the rest of mankind, the pigment lies only between the dermis and the epidermis in small granules. The epidermis is otherwise colorless and transparent, with living cells in the deeper layers and dead cells in the outer layers. These dead outer cells are being constantly rubbed off and replaced by others from beneath.

Lipochromes (fat pigments) contribute to the appearance of red and yellow. Melanin, according to its concentration, contributes to every effect from yellow to black. Haemoglobin (blood pigment) contributes to red and yellow. These coloring matters are produced within the body by little understood chemical processes. The exact origin of melanin is not known. It may be a product of the blood resulting from a disintegration or decomposition of the blood pigment. It is related to the hormone adrenalin. Haemoglobin is a compound containing iron and proteid. In the blood of the average vertebrate, a molecule of haem contains four atoms of carbon and one atom of iron. This is the color. The proteid, which is colorless, contains carbon, hydrogen, nitrogen, oxygen, and perhaps some sulphur. As has been mentioned before, in the true albino there is a total lack of melanin and a deficiency of lipochromes. These pigments give color to the hair and eyes as well as to the skin. The greatest concentration of melanin is found in black hair and in the iris of black eyes. The least is found in the palms of the hands and soles of the feet. Freckles are thought to be due to an abundance of iron. The yellow of jaundice may result from a deficiency of iron, but probably is caused by the absorption of bile into the blood. The blackness, brownness, or blueness of the iris is due primarily to the amount of melanin there. White and gray hair results from a lack of pigment and the presence of air bubbles in the hair, which may or may not have been caused by organisms eating the pigment while chasing microbes.

The upper layers of the skin of a Negro are quite as colorless as those of a white man, as is demonstrated when the skin of a

Negro is blistered. The liquid comes between the outer and the lower layers of skin and appears white, as in other races. If pigment were in the outer layers the blister would not affect the appearance of the skin. As the cells of the lower layers of a Negro's skin move toward the surface, they lose the pigment.

Where the sunlight is most intense, as in the tropics, and where it is reflected most strongly, as in the arctic regions, the natives are dark skinned. Men of lighter races become tanned on exposure to strong sunlight. The actinic rays (beyond violet) of sunlight can be irritating and injurious to the skin and eyes; they can effect chemical changes within the body, coagulate blood, provoke the formation of melanin, and kill living substance. Thus the darkening of the skin when it is exposed to strong light may be a protective reaction. It has been reported that only black pigs can be kept in tropical America.

One theory is that the black man has developed by his eating fruits and vegetables containing manganates and that the white man has evolved by adding salt to his food and by drinking milk. Salt is known to be a powerful bleacher and milk, which contains chlorine, has also a bleaching effect. It is said that Negroes who drink milk and eat meat are not so dark as those who eat only fruits and vegetables.

The redness of blood is influenced by oxygen and carbon dioxide. The rosy cheeks of youth indicate a healthy blood condition, together with a healthy and delicate skin. A white man can appear all colors under certain conditions, so he might more appropriately be called "colored," whereas the Negro, whom we speak of as "colored," is black, which denotes an absence of color. A white man can appear nearly white from fright, loss of blood, etc.; grayish from pain; red from exertion, anger, etc.; greenish from biliousness and introduced poisons; yellow from jaundice; blue from cold, poor circulation, and lack of oxygen; brown from sun tan; purple from strangulation; and black from decay. Men and women employed in munition factories where they handle certain powders have turned a bright yellow. Blue-skinned men have been seen in side shows. The blue in this case is an accidentally introduced pigment. Purple birthmarks are caused by an unusual concentration of melanin. Some Fijians make a practice of

dusting their hair with lime to keep the sun off, and the white lime turns their black hair to a purplish red.

Some colors exhibited by birds, fish, reptiles, and insects follow.

Colors of Some American Birds' Eggs

Varieties of pink: Chickadee, bank swallow, barn swallow, white-breasted nuthatch, Bendire's thrasher, cardinal, brown thrasher, brown-headed nuthatch.

Varieties of light blue: Bluebird, rose-breasted grosbeak, wood thrush, olive-backed thrush, song sparrow, mockingbird, catbird, robin, red-winged blackbird, purple finch.

Varieties of light brown: Long-billed marsh wren, house wren, sharp-tailed sparrow, golden-crowned kinglet.

Predominant Colors of Some North American Birds
(Male unless specified female)

Razor-billed auk: Dark reddish-brown head, greenish-gray back and wings, white breast.

Double-crested cormorant: Orange face, dark grayish-green body, dark reddish-brown back and wings.

Leach's petrel: Medium blue-gray body, brownish-gray wings.

Mallard duck: Green head, light grayish-brown back, purplish-chestnut breast.

Egret: Pure white, with yellow bill and black legs.

Sand-hill crane: Light slate gray, with area of light orange on head.

Woodcock: Dark-brown back and wings, with markings; light-brown body.

Bobwhite: Reddish-brown back and wings, with markings; white breast, with brown markings.

Turkey vulture: Dark brown, with red featherless head.

Mourning dove: Light grayish-brown back and wings; creamy-brown body.

Sparrow hawk: Cinnamon, with pale-rust and white underbody.

Osprey: Dark-brown back and wings, head and body white.

Bald eagle: Dark-brown body and wings, white head and tail feathers.

Screech owl: Dappled brownish gray with lighter breast, also mottled chestnut red.

Belted kingfisher: Bluish-gray back with white breast. Female has reddish band across abdomen.

Ruby-throated hummingbird: Bronze-green back and wings; under parts red, bronze green, and white.

Magpie: Black with underbody of white.
Blue jay: Grayish violet blue with underbody of gray and white.
Redheaded woodpecker: Bright-red head, grayish-blue back, white underbody.
Meadow lark: Mottled dark brown with dusty-yellow underbody.
Red-winged blackbird: All black except a patch of red on each shoulder.
Baltimore oriole: Fore and upper parts, black; under parts, orange.
Purple finch: Pinkish purple and brown; (female) grayish olive with white underbody.
Goldfinch: Golden yellow with brown cap, wings, and tail.
Cardinal: Bright red all over.
Scarlet tanager: In summer, red with black wings and tail, and in winter, red replaced by yellowish green and yellow; (female) yellowish green with yellow underbody.
Purple martin: Steel blue.
Barn swallow: Steel blue with chestnut and red underbody.
Bluebird: Bright-blue back, with cinnamon-chestnut and white under parts.
Ovenbird: Olive upper parts; white under parts, with black spots.

Most American animals exhibit no color in their furs other than many varieties of gray, brown, black and white.

Colors of Reptiles Having Limbs

Green turtle: Dark-brown shell (fat has greenish hue).
Soft-shelled turtle: Greenish brown.
Gila monster: Pink and black. This is the only poisonous (not to man) lizard in the world.
Blue-tailed skink: Slatey black or dark brown, with bright-blue tail and pinkish hue on head.
Frogs: Soft shades of brown, green, yellow, black, and white.
Water newt: Light olive.
Land newt: Brilliant scarlet.
Spotted salamander: Bluish black, with small yellow spots.

Colors of Snakes (Limbless Reptiles)

Poisonous

European viper: Pale grayish green, with dark diamond-shaped marking on top. This is the only poisonous serpent found in Great Britain.
Western pygmy rattlesnake: Warm gray with large brown spots.

Coral snake: Broad bands of bright red and black, separated by narrow yellow bands.

Moccasin: Blending bands of dull blue and brown.

Diamondback rattlesnake: Large brown diamonds with dull-blue borders, separated by yellow.

Copperhead: Pinkish brown, with dark reddish-brown dumbbell-shaped markings and copper-colored head.

Harmless

Water snake: Gray with dark-brown rings; also, light blue with darker rings.

Scarlet milk snake: Wide, vivid red-orange bands with black borders, separated by light orange.

Green snake: Light grass green above, yellowish below.

Mud snake: Dark gray, with large dull-red spots on sides.

Pine snake: Light tan, with large brown spots.

Scarlet king snake: Broad red and yellow stripes, divided by narrow black bands.

General Colors of Some American Fish

Sea bass: Dull bluish or brownish black.

Smallmouthed black bass: Dull golden green above, white below.

Red snapper: Pink.

Brook trout: Green and pink.

Canadian red trout: Dull green above, red below.

Rainbow trout: Bluish top, silvery sides spotted with black, rose-red lateral band.

Eastern brook trout: Red spots, blue markings.

Sunfish: Olive and silver, marked with blue and orange.

Pickerel: Green above, with various markings.

Yellow perch: Black bars on a yellowish body.

Bluefish: Blue-green above, sides silvery, white below.

Yellowtail: Bright steel blue, with dull silvery and yellow sides and a yellow tail.

Spanish mackerel: Greenish blue above; sides silver, with dull-orange spots.

California redfish: Black at both ends, red in the middle.

General Colors of Some American Insects

Beetles, Grasshoppers, etc.

Praying mantis: Light green and brown.

Locust (short-horned grasshoppers): Light brown.

Katydid (long-horned grasshoppers): Green.

Beetles of various kinds exhibit the following color combinations: Bright green with yellow and white; black and brown; blue-green and red; violet, green, and gold; metallic blue-black; reddish brown or yellow-brown with black spots; black with yellow or reddish-brown spots; metallic greens, blues, and copper colors; greenish gray with black spots; rich blue and rich orange-yellow; brick red and black spots.

Butterflies

There are in this country over 600 families of butterflies, many of which are brilliantly colored in the adult stage and also in the larva and caterpillar stages.

Monarch: Deep orange or tawny brown, with black borders; larva, light green with gold dots.

Zebra swallowtail: Bands of black and greenish white with a red spot on each hind wing.

Tiger swallowtail: Yellow with black borders; larva, dark green with greenish-yellow spot having a black border, with a black dot in the center of the yellow spot.

Spicebush swallowtail: Greenish black, with rows of yellow dots and bluish-green dots and two red spots.

Black swallowtail: Black, with rows of yellow spots and blue spots and two red spots.

Common sulphur: Greenish yellow, bordered with brownish black and having two black spots and two orange spots.

Parsley butterfly: Black, with rows of yellow, and having three violet dots and one red dot on each hind wing.

Grass nymph: Soft grayish brown, with black spots and white areas.

Common wood nymph: Brown; on front wing two black spots having blue centers, and around the spots bands of yellow.

Red admiral: Brownish black, with bright orange-red band across the forewings and white spots ahead, deep-orange band on the margin of the hind wings.

Parnassius: Grayish-green body, greenish-white wings, with four black dots on the front wing and two red dots on the hind wing.

Moths

There are over 6,000 species of moths in this country.

Rosy maple: Wings yellow, banded with rosy red.

Bella (tiger moth): Pinkish-red hind wings, with black branching border;

yellowish-red forewings, with six bending white bands containing small black spots.

Luna: Delicate greenish-yellow tint; leading edge of forewing, grayish-purple tint; body, golden; two bright yellow-white spots on hind wings.

Hummingbird sphinx (clearwing Thisbe): Small wings; body, front part yellowish green, with band of brown and brown tail; clear transparent wings bordered in dark brown.

Imperial: Rich yellow, with pink-purple marks.

Io: (Male) Light yellow-brown, with one black spot on each forewing; (female) brown forewings, dusty-orange hind wings with one dark-blue spot and curved line in each.

Underwing: Forewings, grayish or brownish, with zigzag line; hind wings, brilliant colored, black with broad bands of red, yellow, or white.

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PART THREE

Colors by Man and How Produced

7

DYES

The staining of materials with coloring matter has been practiced for thousands of years. In the beginning, fabrics and other substances were stained with the juices of fruits, flowers, and other vegetable sources of coloring matter. A blue was obtained from the leaf juice of the indigo plant. Besides, various small shellfish when crushed yielded a colorless fluid which, after exposure to the air, turned purple (Tyrian dye). A dark-brown dye (sepia) was obtained from the ink of the cuttlefish. A red was obtained from the root of the madder plant and from the female of an insect called "kermes"; but later a better source of red was found in the female of the insect called "cochineal." The stigmas and styles of the safflower (saffron) and the yellow locust, logwood, and old fustic supplied yellow dyes. These were all natural dyes, developed by the chemistry of nature and transferred by man to materials mainly by simple contact, which was nothing more than staining. The dyes as thus used may or may not have penetrated the fibers of the material to which they were applied, and they were affected by moisture, sunlight, etc.

The discovery of mordanting was made about 2000 B.C. or earlier. Mordanting is the combining with a dyestuff of some other substance that forms an insoluble compound and produces a fixed color in the fibers of the material. Many acids and chemical compounds serve as mordants, their effectiveness depending on their chemical composition and that of the material to be dyed. Wool attracts dyes best, silk next, and cotton last. Many natural substances are still being used as dyes by natives in various parts of the world and in some instances by manufacturers, but for the most part dyes are now being produced synthetically.

The artificial production of dyestuffs involves complicated chemical processes. The first book on the subject was published at Venice, Italy, in 1429. In chemistry, color is evolved by changing the structure (molecular arrangements) of matter. Thus ben-

zene, which is colorless, when it is changed to quinone becomes yellow. Lead nitrate and sodium chromate (both colorless) when they are mixed produce a precipitate of lead chromate that reflects the yellow rays of light and absorbs the others, thus appearing a bright yellow. This product, called "chrome yellow," when applied to some material lends it that quality. Some idea of how color is produced by chemistry may be obtained from the following simple experiments.

Mix manganese dioxide with sodium hydroxide and a few crystals of sodium nitrate or potassium nitrate. Heating this mixture produces sodium manganate or potassium manganate. Dissolve the residue in water and the solution is green. If you blow your breath through a tube into this solution, it turns first red and then violet. The carbon dioxide in the breath has changed green manganate into purple manganate.

Copper sulphate crystals dissolved in water produce a blue solution. Add a few drops of ammonia and a light-blue precipitate of copper hydroxide appears. If you add more ammonia and stir, the solution becomes a deep azure blue.

Produce a dry powder by heating copper sulphate crystals. Add to this a drop of water and the powder will become blue.

Dissolve cupric chloride (copper salt) in a very small amount of water and the solution is yellow. Add more water and it turns green. Add still more water and it turns blue.

Dissolve chrome alum (potassium chromium sulphate) in water and it is a bluish red. Heat it to 70° C. and it becomes green.

Dissolve potassium bichromate in water and the solution appears red-orange. Add, drop by drop, a solution of potassium hydroxide or potassium carbonate. After a while it turns yellow; the potassium bichromate has been changed to potassium chromate.

Iodine when it is heated changes color. Red iodine and white starch produce a blue.

The coal-tar color industry is based on changing the structure of chemical compounds. When the structure of a substance is changed, its power to absorb light is altered and it changes color. Coal-tar and aniline dye manufacture was introduced about one hundred years ago. In 1856, Perkin in England produced the first organic dye. Until the nineteenth century, most synthetic colors

were made from minerals and their compounds. In 1828 Woehler made the first organic compounds. Coal tar comes from the distillation of bituminous coal. Aniline dyes are derived from nitrobenzene (produced by action of nitric acid on benzene). These colors all result from complex compounds of carbon with other elements, such as hydrogen, nitrogen, oxygen, and sulphur. Most of the dyestuff in this class comes from such colorless hydrocarbons as naphthalene and anthacene (solids) and benzene, toluene, and xylene (liquids).

Organic chemistry deals with carbon compounds. Over 2,000 individual color compounds built around carbon are in constant use, while only about 100 coloring matters derived from any of the other elements are used.

Common table salt (sodium chloride) provides pure sodium and chlorine for the dyeing industry. Salt exhausts the dye — causes the color to affix itself in full strength.

Eosine results from the action of bromine on fluorescein. It provides a red-rose color used in silk dyeing and in cosmetic manufacture, among other industries.

A standard ink is prepared from a dyestuff, which is combined tannic acid, gallic acid, ferrous sulphate, hydrochloric acid, and carbolic acid. The material from which some fountain pens are made can affect the color of inks. Most ink stains can be removed with an alkali, such as ammonia.

The black of carbon papers is a combination of carbon or gas black, wax, kerosene, oil, and rosin. Colored carbon paper is produced with an aniline dye and some fatty acid (stearic or oleic acid).

Some soap dyes are alum for white, copper for green, and ferrous sulphate for red.

The dyes for rubber goods include lithopones for white, antimony sulphide for red, iron oxide for yellow and red, litharge for black, and white lead for gray.

Some Easter-egg dyes are said to contain lead or arsenic, which is poisonous. Such dyes may smell like paint or varnish. If the dry skins from red or yellow onions are put into boiling water with eggs, the eggs take on a deep mahogany color.

Carmine is a natural dyestuff that yields the colors orange,

crimson, and scarlet. It is obtained from the female cochineal insect, which is found in Peru and Mexico. The Spaniards found it being used in Mexico in 1518, and the insect was later cultivated in Spain and Algeria. The insects are brushed from the cactus on which they live and then are killed either in hot water or by exposure to the sun, steam, or heat of an oven. The color obtained depends on the method employed. Natural carmine has been almost entirely replaced by synthetic dyes.

The wool from which rugs are woven, after a lengthy process, is scoured and wound in skeins. The coloring of the yarn proceeds as follows:

> While the skeins are still damp from their recent scouring, they are hung on racks and lowered into great vats containing boiling water and aniline dye. Wool has a natural affinity for aniline, which it absorbs, thus adding to its bulk. From the basic colors, red, blue, and yellow, more than 12,000 shades of color are obtained in the Mohawk dye vats. Constant expert supervision and testing are necessary to get any of the shades perfect.
>
> Now, after all the adventures encountered in getting raw wool, after the washing, curing, sorting, carding, spinning, dyeing, etc., the yarn is ready at last for the loom.[1]

Dyed material fades when an incorrect or an insufficient mordant has been used. In such cases, water, air, and sunlight restore the substance to its original structure and cause it to lose color.

Dyes are widely used to color foods, and there are both natural and synthetic food dyes. Some natural and harmless food dyes are

Saffron (orange and yellow): Produced from the dried stigmas of the safflower. This has been used from ancient times.

Anatto: A reddish dye from the pulp around the seeds of a tropical tree (*Bixa orellana*), used to color butter, cheese, rice, and soup.

Palm oil (orange): From pulp of seeds of oil palm tree. Palm oil is used in coloring many food preparations. To produce lighter colors, it can be bleached with sodium bichromate and hydrochloric acid.

Some synthetic food dyes that are harmless when properly made are naphthol yellow S, yellow OB, ponceau 3R, orangel, ama-

[1] From "The Romance of Rug Weaving," by Mohawk Carpet Mills, Inc., Amsterdam, N.Y.

ranth, tartrazine, guinea green B, erythrosine, indigo disulphonic acid, etc.

The following synthetic colors have been used in foods, but they are forbidden under pure food laws.

Metallic: Compounds of antimony, arsenic, cadmium, chromium, copper, mercury, lead, zinc.

Vegetable: Gamboge (yellow), a gum resin. Used in medicine as an emetic or a cathartic.

Coal tar: Picric acid (carbazotic acid), Victoria yellow (dimitrocresol), Manchester yellow (a derivative of naphthalene), imperial yellow (aurantia), and Aurine (rosolic acid).

Butter yellow, a coal-tar color consisting of dimethylaminoazobenzene, is forbidden by the Food, Drug and Cosmetic Act to be used in coloring cosmetics. It is known to possess carcinogenic properties, which means that it can cause cancer.

The Food and Drug Administration lists the following coal-tar dyes that are certifiable for use in foods, drugs, and cosmetics, subject to certain general specifications. These dyes, which are all designated by numbers in the catalogue of specifications, are brilliant blue FCF, indigotine, guinea green B, light green SF yellowish, fast green FCF, orange I, orange SS, ponceau 3R, amaranth, erythrosine, ponceau SX, oil red XO, naphthol yellow S, naphthol yellow S-potassium salt, yellow AB, yellow OB, tartrazine, sunset yellow FCF.

As an example of specifications, that of naphthol yellow S (FD and C yellow No. 1) follows:

Disodium salt of 2,4-dinitro-1-naphthol-7-sulfonic acid.
Volatile matter (at 135° C.), not more than 10.0 per cent.
Water insoluble matter, not more than 0.2 per cent.
Ether extracts, not more than 0.1 per cent.
Chlorides and sulfates of sodium, not more than 5.0 per cent.
Mixed oxides, not more than 1.0 per cent.
Martius yellow, not more than 0.03 per cent.
Pure dye (as determined by titration with titanium trichloride) not less than 85.0 per cent.

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8

PAINTS

This chapter is devoted to a brief consideration of the composition and nature of some of the industrial colors.

No one knows when man first made paint. In caves of France and Spain evidence has been found that man was mixing colored earth with animal fat and applying it to rock walls, to paint representations of animals, more than fifteen thousand years ago. We still mix colored earths with oil to make paint in some instances. The early man effected four colors—black, brown, red, and yellow. About the year 2500 B.C., there seem to have been only six colors in use, whereas today several hundred different colored paints are available, although it has been estimated that the majority of painters use only from 12 to 18 colors.

There are two large groups of colors: (1) those produced from minerals or other inorganic matter, such as earths and clays, and (2) those produced from animal, vegetable, or chemical dyes.

These various methods of manufacture and various ingredients are being used or have been used to produce certain colors, some of which are mentioned here. However, except for the earth colors, most colors are now made with synthetic dyes. Harold Speed says in his book "Oil Painting,"

> All the earth colors are good. They are as near absolutely permanent as anything can be. They have good body, with the exception of terra vert, and they have a nobility and dignity about them that the vegetable and mineral colors do not possess. Some care should be taken in selecting earth colors as they vary considerably in different makes. Being natural-colored earths they vary in hue and some artists' colormen have the monopoly of a better variety than others, having bought up the whole of a good find.

Pigments (the coloring matter) are insoluble particles that are held together by, but never become a part of, the vehicle or medium

(oil, etc.). Dyes, on the other hand, may in the chemical process become a part of the medium (chemistry effects changes in molecular structure). Pigments may be prepared chemically or they may be procured very simply from the source. Natural pigments are removed from the material in which they are found. In an early stage they appear as finely divided, insoluble, colored dry powders. The powder is pounded, ground, sieved, heated, and treated in various ways for removing impurities and refining it. The temperature at which it is "burned" influences the color that it ultimately makes. Eventually the powder is mixed with a medium to bind it. Some mediums are olive oil, linseed oil, copal oil, poppy oil, wax, mortar, glue, glycerine, resin, etc. After grinding is completed, the mixture is thinned as desired.

White

One of the most useful "colors" is white. Not only is it used alone, but it is the backbone of most of the tints, under various names. White paint is derived from lead, zinc, barium, lithopone, titanium, antimony, alumina, calcium carbonate, calcium sulphate, kaolin, gypsum, asbestine, silica, etc. Some of these substances are more useful as extenders or adulterants than as bases. They may be included with a more substantial base, to lower the cost.

Whites with a lead base are flake white, Kremnitz white, and silver white. White lead was known and used by the Romans and the Chinese more than two thousand years ago. It is still very extensively used, because it has a substantial element-resisting body. In the manufacture of white lead, metallic lead "buckles" are corroded by acid. In about three weeks the buckles are reduced by this corrosion to a white powder. This powder is washed, dried, and ground. A medium is added and the grinding is continued until the product is satisfactory. Most paints that have a lead base are poisonous and should not be used on the inside of a house or on furniture. Artists who use lead paints and who wish to keep their health should not put paint brushes in their mouths. White lead is affected by some gases and by light and, in time, may turn yellow and then black. It is not compatible with the copper color,

emerald green, or with the sulphur cadmiums, vermilions, and ultramarines. In spite of these limitations, flake white (purified lead carbonate) is preferred by many artists who know how to use it. It has a character of its own.

Zinc white is not a poison and is unaffected by gases or light. It is said to have been discovered in 1780 but used little before 1850. In manufacturing, the metallic zinc ore is mixed with hard coal and "cooked" at a high temperature. A poisonous vapor, which is formed by the great heat, is carried away in long pipes. As the vapor cools, it turns to a white powder. This is then processed as other pigments are. Chinese white is a name for zinc-white water color. Zinc white is permanent and can be mixed freely with any other paint. It dries slowly but becomes very hard.

Titanium (oxide): Exceeding zinc or lead white in body and covering power. It has been in use only a few years.
Antimony (oxide): Developed during the First World War.
Lithopone: Obtained by simultaneous precipitation of zinc sulphide and barium sulphate and subsequent calcination.
Barium (sulphate): Base of the water color, permanent white.
Alumina (hydrate): White lake.
Calcium (carbonate): Whiting.
Terra alba (white earth): From gypsum, kaolin, magnesia, or calcium sulphate.

No pigments produce pure white or pure black or completely pure colors.

A small amount of blue or violet added to white gives it the appearance of greater whiteness.

The hiding power of paint follows its refractive index. These indexes are given for the following whites:

White Paints	*Indexes*
Aluminum hydrate	1.48
Barium sulphate	1.64
Lead sulphate	1.93
Zinc oxide	2.02
Zinc sulphide	2.37
Titanium oxide	2.76 (most opaque)

Black

Ivory black: From ivory chips charred in a closed vessel.

Bone black: From bones reduced to powdered charcoal by heat. Blacks from ivory and bones are considered "warm" because of their comparatively brownish appearance.

Blue black: From the destructive distillation of wine lees.

Lampblack: Almost pure carbon; the soot resulting from burning natural gas or mineral oils in insufficient air, which causes incomplete combustion.

Vine black: Wood charcoal; carbonized twigs and vines. Blacks from wine dregs, soot, and wood charcoal are considered "cool" because of their comparatively bluish appearance.

Mineral blacks: From coal dust, shale, magnetite, and graphite.

Davey's gray: From slate. Other grays are usually simply mixtures of various colors, such as red, yellow, and blue, in various proportions, or of black and white.

Red

Red pigments are produced from metals such as lead, mercury, and iron in various forms and from dyes.

Red lead (oxide): Produced by heating litharge in air. A binder, such as linseed oil, is added to the dry powder to make paint.

Chrome red: Lead chromate. Used as a base for various organic lake pigments.

Iron oxides: Hematite (ironstone, an iron ore), red ocher (an earthy iron ore), red bole (a crumbly clay), etc.

Venetian red and *light red:* From iron oxides (earth colors). Frequently produced by roasting yellow ocher.

Indian red: From iron oxides. Used by the ancients. Has a purplish appearance, especially when mixed with white.

Vermilions: Red sulphide of mercury. Used by the Romans in its natural state. Produced artificially since the twelfth century. Not compatible with lead and copper colors. Some varieties darken with time.

Cadmiums (orange): Sulphide of cadmium.

Madders: Originally from the dye purpurin, obtained from the root of the madder plant; now almost entirely produced from anthracene (a coal-tar product).

Alizarins: Similar to madders, having same source. Raw earths and lead colors added. Not permanent.

Lakes: The term "lake" is applied to all pigments prepared by the precipitation of dyestuff on a base, or "carrier." Various substances are used as bases, such as barium sulphate, zinc oxide, lead sulphate, red lead, litharge, china clay, green earth, etc. The base may or may not absorb the dye. Crimson lake is from the dye carmine (from cochineal) precipitated on an alumina hydrate base. Madder lake is from the dye purpurin precipitated on an alumina hydrate base.

Mars reds: Prepared clay stained with hydroxides. Yellowish or bluish.

The iron-oxide colors are the most useful and have a character that is lacking in others. They have great staining power and are permanent. The reds produced from dyes are artificially brilliant and are so fascinating that they must be used with restraint for a pleasing effect. They are especially useful in tints. Yellow ocher may bleach alizarin crimson in time. Rose madder or alizarin crimson painted over vermilion may approximate the red of the solar spectrum.

Yellow

Ochers: Natural earth containing iron mixed with a binder (ancient).

Chromes (lemon to orange): Chromates of lead, zinc, barium, and strontium (from the early nineteenth century).

Lemon yellow: Barium chromate. Considered the nearest approach to spectrum yellow.

Cadmiums (lemon to orange): Cadmium sulphide. As is true of other pigments, shades and tints depend on the method of preparation. The genuine cadmiums are expensive. Cheaper varieties are produced by inclusion of cadmium carbonate or zinc sulphide or cadmium selenide; not permanent. (From the early nineteenth century.)

Aureolin: Cobalt and potassium nitrate (1861).

Lakes: Various yellow dyes precipitated on an alumina hydrate base.

Mars yellows: Artificially prepared clays stained with iron hydroxides.

Naples yellows: Lead antimoniate or mixtures of zinc white, cadmium yellow, and light red. May become dull and greenish.

Gamboge: A gum resin. Does not mix with some metallic pigments and fades in light.

Blue

Prussian blues (reddish): Complex ferric ferrocyanides (discovered in 1704). Contain potassium, ammonium, or sodium. Tend to turn black

and to absorb any color mixed with them. A green or a violet containing this pigment turns blue in time. Antwerp blue is a prussian blue diluted with alumina hydrate. Also called "Chinese blue."

Ultramarine (reddish): Originally made from the natural stone, lapis lazuli (from the twelfth century). Now, owing to scarcity of lapis lazuli, the pigment is developed from a complex compound of soda, sulphur, carbon, and clays (sodium sulphide and silicate of aluminum). It becomes opaque in time.

Cobalt: Cobalt-aluminum oxide (from the early nineteenth century). Appears violet by artificial light. Nearest color to spectrum blue.

Cerulean: Cobalt-tin oxide.

Indigo: Originally from plants found in India and elsewhere (ancient). Used principally in water color and as a dye. Present dyestuff is synthetic.

Purple

Cobalt violet: Cobalt phosphate (1850). Permanent and useful.

Magenta: Precipitate of rhodamine on an alumina hydrate base. Fugitive.

Mauve: Precipitate of methyl violet on an alumina hydrate base. Fugitive.

Green

Viridian (verte emeraude, emerald green): Hydrated chromic oxide (1834). Permanent and transparent.

Permanent green: Oxide of chromium. Dull, opaque, permanent.

Terre verte: A green earth containing ferric silicates. Has weak tinting power.

Chrome greens: Mixtures of chrome yellows and prussian blues.

Verdigris: Copper acetate (poison). Known to the Romans.

Paris green: Arsenic and copper acetate (poison).

Brown

Sienna: Natural earths containing oxides of iron and/or manganese. Yellowish brown when raw (raw sienna), and reddish brown when burnt (burnt sienna).

Umber: Same as above. When raw sometimes has a greenish appearance. Darkens in time and alters colors mixed with it.

Ocher: Clay stained with ferric hydroxides.

Bone brown: Partially burnt bones.

Bitumen (*asphaltum, mineral pitch*): A mixture of hydrocarbons dissolved in coal tar or naphtha. Never dries and decomposes in sunlight.
Italian pink (*pinkish brown*): A precipitate of the dye from quercitron bark.
Van Dyke brown: Natural earth containing partially decayed vegetable matter (Cassel earth, Cologne earth). Fades in light.
Sepia: A dark fluid obtained from a Mediterranean cuttlefish. Used in water colors only.

Buff is a mixture of yellow ocher and white. *Cream* is a mixture of chrome yellow and white.

Metallic paints are produced by mixtures of finely powdered metals or alloys, such as aluminum, copper, bronze, gold, etc., with a medium, such as copal or celluloid varnish.

Fireproof paints are produced by adding asbestos, borax, sodium, tungstate, etc., to oil paints.

In the Orient, paints have been produced from powdered precious stones and minerals, as pink from coral, blue from lapis lazuli, silver from crystal, and green from jade.

Cellulose paints are derived from nitrocellulose in acetone or amylacetate (flammable).

Luminous paints are produced by mixtures of calcium oxide, sulphur, starch, bismuth nitrate, sodium chloride, and potassium chloride. The mixture is heated, ground, and held together with water or varnish. This product is fugitive and requires exposure to sunlight at frequent intervals for renewal of its light.

Phosphorescent paint can be produced by making zinc sulphate radioactive by association with radium and mixing the product with a binder. This may continue to glow for two years.

Fluorescent paints are produced by mixtures containing fluorescent minerals. According to the mineral used, various colored lights will be emitted when the product is exposed to ultraviolet radiations. The minerals are mixed with nonfluorescing pigments to effect various color changes in advertising and theatrical work. Regardless of what color a paint may appear under ordinary illumination, if calcite is mixed with it, it will appear red under ultraviolet light. Willemite effects green; fluorite, blue; wernerite, yellow; hyalite, green; etc.

Cosmetics

Indian war paint: From iron salts (fruit juices and oxides of iron) plus vegetable extracts, colored clays, and animal fats, powdered chalk, and fresh beet root.
Henna: A dye from leaves of the henna tree.
Lipsticks: Carmine plus a harmless lake.
Rouge: Same as above, plus eosine.
Powder: Talc plus yellow ocher, vegetable dyes, lake colors, etc.
Clown white: Made with a zinc oxide base.
Minstrel black: Before grease paint, made with burnt cork and glycerine.
Grease paint: Produced in every color and in black and white. Made from oil, spermaceti (a waxy substance procured from the sperm whale) and wax.

Primitives used chalk and white clay on their bodies.

In the Greek drama, bacchantes smeared wine dregs or mulberry juice on their faces.

Egyptians painted green under the eye. They used kohol (kohl, a powder of antimony or galena) to blacken lids, lashes, and eyebrows.

Romans used white lead and chalk to whiten the skin, kohol for eyelids and lashes, and fucus (a vegetable rouge) for cheeks and lips.

Mediums

The early painters used wax, white or yolk of eggs, water, honey, mortar, glue, gum, glycerine, and resin as vehicles (mediums). Oil was first used in mixing colors about the year 1400. The Van Eyck brothers (Flanders, 1400) developed the oil technique to a high degree of perfection. All kinds of material have been painted on, but up to the end of the Renaissance wood panels were most universally used. Mahogany panels are still being used. Direct painting in wet plaster (fresco), practiced by the Romans, is an art that is not dead yet.

Linseed oil: Obtained from flaxseed. The oil is pressed out and clarified and bleached by exposure to sunlight. It is used both raw and boiled. The boiled oil is darker and dries more quickly than the raw. Linseed

oil is commonly used in grinding pigment powders and with a thinner (usually turpentine) in painting.

Turpentine: An oleoresin procured from various trees. It is the distilled sap. The residue is rosin. The refined pure spirit completely evaporates and leaves no stain.

Mineral spirit: A volatile oil from petroleum.

Poppy oil: From poppy seed. Lighter than linseed oil.

Dryers: Containing salts of lead, manganese, or cobalt.

Varnishes: Containing resins (cobalt, amber, mastic, etc.)

Shellac: Originally from a resinous substance (lac) secreted by an insect (*Carteria lacca*); now usually made from the sap of certain trees.

Megilp: Linseed oil and mastic varnish.

Water Colors

In the preparation of water colors, various mediums are used, such as gum arabic, albumen, isinglass, emulsified glue, glycerin, casein, etc.

Tempera: Essentially an opaque water color.

Water color is mostly used in transparent washes on white or tinted papers. When water color is used opaquely and in the manner of oils, the method is called "gouache."

Acknowledgment is given to the following sources of information. See also Part Seven.

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9

FABRICATIONS

Glass

Glass is manufactured from various substances, including silica (white sand), vegetable ashes, carbonate of soda (soda ash from seaweed), potash, lime, oxide of lead, arsenic, and charcoal. Various metallic oxides are introduced to give it color, the resulting color depending on the quantity of oxide used, the method of mixing, and the temperature and time of heating. Lime gives glass hardness; oxide of lead gives it brilliance; soda and potash make it more pliable.

Red: Effected with selenium, copper, iron, chromium; pink, with lithium and manganese; ruby red, with finely divided gold (cannot be used in photographic darkroom.)

Yellow: From chromium, uranium, titanium, iron, cadmium (sulphide), silver salts, carbon, sulphur.

Blue: From cobalt, copper, titanium, manganese and aluminum.

Green: From copper, chromium, iron, uranium.

Purple to brown: From nickel and manganese.

Opaque white: From stannic oxide.

Iridescent effects are produced by treating the hot glass article with vapors of salts, tin chloride, ferric chloride, etc.

In the fourteenth century it was discovered that a solution of silver would impart a stain to glass (lemon to orange). This, when applied to a blue glass, produced a green effect. At that time clear glass was frequently colored by simply dipping it into molten colored glass. About the middle of the sixteenth century ordinary powdered glass was mixed with a metallic oxide and a binder (gum, etc.), applied to clear or colored glass, and fired in a kiln to fuse. The first factory in North America (1608) was engaged in making colored glass beads for trading with Indians.

The Egyptians, who did not blow glass but made their vessels over an earthen core, produced opaque glasses of blue, yellow, green, white, and black.

The Greeks made little use of glass, but the Romans developed the art of glassmaking to a high level. The art of blowing glass may have had its start in Syria about 200 B.C. Blown glass was produced by the Romans, who also molded glass and who created cameo glass. In this process layers of various-colored glass were superimposed one on another, usually opaque white or black with one or more colors. The top layer was cut away, as might be desired, with an emery wheel so as to expose the color of the layer below. For more than one thousand years after the fall of the Roman Empire very little progress was made in this art, which had renewed impetus, however, in Venice, Italy, in the sixteenth century.

During the Gothic period, from the twelfth to the sixteenth century, the art of making stained glass for cathedral windows was developed to a high degree of perfection. The best work revealed the richest colors imaginable. Strong deep reds and blues predominated in most of the compositions. All details were subordinated to design and color harmony.

Enamel

The base of enamel is a colorless, transparent compound called "flux," which is composed of silica, minium, and potash. The flux is colored by the addition of metal oxides while in a state of fusion. The compound is applied to a metal support and fired. Fine gold or pure copper provide the best support. The flux is fusible at a lower temperature than the metal to which it is applied. Usually an opaque white enamel is applied to the metal first, after which the colors are superimposed and fired on. The complete process is complex and the resulting colors depend upon various conditions, upon the methods used, and upon the kind, quality, and proportions of material used.

Turquoise blue, for example, is produced from black oxide of copper and a large amount of carbonate of soda, while yellow-green is obtained from black oxides of copper and a greater portion of red lead. All transparent enamels can be made opaque by the addition of calcined tin and lead (calx). White enamel is obtained by the addition to the flux of stannic and arsenious acids. Enamels are extensively used today in manufacturing and advertising and

have been employed in the making of jewelry and other art objects for several hundred years. In the fifth and sixth centuries, the Byzantines made ornaments in which the enamel was applied to a gold base and the different colors were inlaid between partitions. This kind of decoration, known as "cloisonné" work, is still practiced in the jewelry trade. In the process, the powdered glass and other materials used are put into the desired spaces in the gold shell and are then fused, after which the surface is ground smooth and polished.

Pottery, China, and Porcelain

Man has been modeling vessels out of clay and glazing them for at least four thousand years. Pottery represents the coarser vessels, either glazed or unglazed. Chinaware is the term that is loosely applied to all crockery, although originally it referred to a very high type of earthenware made by the Chinese, which was really porcelain, as the finest examples of such work are now called. These arts come under the general designation of ceramics.

In general, the clay or earth is first modeled and then fired to the desired hardness. Next it is decorated and fired again. Finally it is glazed and then fired once more. The clay may, of course, be glazed without having any decoration applied.

The earliest colors were natural clays so varied in composition that, when fired, they took on every shade of color. Some of these earths contained iron, manganese, and cobalt. Glazes are derived from alkalines, lead, feldspar, and salt. The Persians, Syrians, and Egyptians, centuries before the time of the crusades, glazed with clear soda and lime. Some of the early glazes were colored glasses containing copper or iron (green, turquoise, or yellow). During the Ming dynasty in China, cobalt was the only substance known to the Chinese that was suitable for coloring their porcelains, as it alone could endure the heat necessary to melt the glaze. In any method of pottery decoration, the color possibilities are largely dependent on the temperature at which the color needs to be fired. Thus the clay colors are most limited in range, the underglaze colors next, and the onglaze least. Two or three hundred years ago potters first mixed gold, platinum, or silver with a small amount of fusible ground glass and fired it to the glaze.

Porcelain is manufactured today essentially as it was in the eighteenth century. The finest material for such work is Kaolin, a pure white clay until recently obtainable only in Germany. It can now be obtained in the United States, also. To this are added feldspar, which has been cleaned and from which the iron has been removed, and quartz. The mixture is molded, dried, and baked. The resulting hard, dull, white object is then dipped into a liquid composed of the same ingredients, in which quartz and feldspar predominate. This baking requires from 20 to 30 hours. The object is then slowly cooled, a process that may require about 3 days. It is then painted with a mixture of glass powder and dye, after which it is heated rapidly and cooled rapidly. Porcelain, characterized by particular delicacy, is thin, translucent, and resonant. The Chinese were so proficient at the art that they produced articles as thin as paper and having musical qualities.

The patina exhibited by many antique objects of glass and glazed ware is in many instances the result of years of oxidation and exposure to various gases and is not the evidence of any special skill on the part of the artisan.

Artificial Gems

Every year about 20 million carats of rubies and 12 million carats of sapphires are manufactured. Any precious stone can be reproduced by man, but it costs more to make a diamond than to procure it in the normal way. Other stones have not sufficient value to justify the expense of making them. The artificial stones may have the chemical, physical, and optical qualities of the natural gems.

Diamonds have been produced artificially, but not commercially, by dissolving carbon in pure iron at great heat and plunging this into molten lead. Sudden cooling causes tremendous internal pressure and the liquid carbon is crystallized into small diamonds.

Very small emeralds have been produced, but the process is too expensive for commerce. Sapphire chips cannot be successfully fused because the heat destroys the color. They are produced from oxides of aluminum, iron, and titanium. Sufficient heating results

in the proper blue color, but too much heating makes the product pink. A spinel can be made with cobalt and magnesia, but a sapphire cannot.

A ruby can be reconstructed by fusing ruby chips or it may be produced from pure alumina with an oxyhydrogen torch. The great heat makes oxide of aluminum, and the color comes from a small amount of chromic oxide, which is added. The stone is built up in layers and the light coming through these layers effects the pigeon-blood red appearance. If the alumina is not absolutely pure, failure will result. For instance, the presence of 0.0005 of 1 per cent of magnesium oxide would change the color to a brick red.

Both synthetic rubies and synthetic sapphires require cutting and polishing, as the natural stones do. Synthetic stones made from a combination of parts of real and imitation substance (paste) may be detected by immersing the unmounted stone in boiling water or alcohol or chloroform. Under these conditions such a product will fall apart.

Imitation pearls are made from glass beads by coating them with powdered isinglass and certain fish scales.

Rhinestones are of glass or "paste" composition, to which color is sometimes added. They may have a natural high luster or be backed like a mirror with some substance so as to reflect the light.

Fireworks (Pyrotechnics)

Originally these displays were without color and the materials used were saltpeter and charcoal, plus potassium chlorate, magnesium, and aluminum. Color was introduced early in the nineteenth century. Every fireworks composition includes at least one ingredient that has a supply of oxygen with which it readily parts. The composition does not depend on oxygen from the air for combustion. The oxygen suppliers are saltpeter (potassium nitrate) and potassium chlorate.

There are two classes of compositions: (1) those that provide force and sparks and (2) those that provide flame (white and colored). Compositions of the former class are produced from potassium nitrate, sulphur, and charcoal, finely powdered. Finely

powdered aluminum produces a brilliant white fire. Iron, steel filings, and lampblack produce sparks. Nitrate of lead and barium and sometimes gunpowder are added.

In compositions of the second class, white fire is effected by potassium nitrate together with salts of antimony or arsenic and sulphur. Other compounds may depend on potassium chlorate or perchlorate. The combustion of potassium chlorate, etc., in combination with a metal salt has the effect of turning the metal present into gas and produces a colored flame. Salts used for red are the nitrate, carbonate, or sulphate of strontium; for green, the nitrate, carbonate, or chlorate of barium; for yellow, the nitrate, carbonate, or oxalate of sodium; for blue, the sulphide, carbonate, or arsenate of copper in combination with calomel (mercurous chloride). Although copper burnt in a blowpipe flame produces a green color, the salts are used only for blue. The chlorine present with potassium chlorate makes a blue flame. The addition of calomel produces more chlorine and a deeper blue color results. Magnesium powder may be added to these for extra brilliance. To the whole composition, binders and fillers are added for bulk and balance. The arrangement of these materials in the container controls the time, sequence, and nature of the display.

A patent has been obtained for a process to provide color to tobacco smoke. The inventor claims to have harmless chemicals that, when incorporated with the tobacco, will produce smoke of any desired color to match or harmonize with the smoker's ensemble.

Electric Lights

There are three classes of colored electric lights: (1) ordinary bulbs with coloring matter applied either outside or inside; (2) bulbs containing argon gas or some other gas that will produce ultraviolet light, with fluorescent matter applied on the inside of the bulb, according to the color desired; (3) bulbs containing various gases which, under the influence of an electric current, produce colored light. In the case of neon lights, high voltage is applied to tubes that are fitted with electrodes and contain neon gas. Such tubes normally glow with a reddish-orange light, but the introduction of a small amount of mercury makes a light-blue

light. Other colors are effected by adding other gases or by using colored glass or by a combination of these means. Argon and krypton gas are used in effecting blue; helium gas in a yellow tube effects golden light; argon gas in an amber tube effects green.

The following materials contribute to the color effects produced in arc lights.

Red: Strontium, yttrium.
Yellow: Calcium fluoride.
Blue: Uranium, iron, mercury.
Green: Erbium, thallium, mercury.
White: Helium.

Various rays of light make various substances visibly fluorescent. Fluorescence, as has been previously noted, is the quality of emitting light while excited by light. It is said to be due to minute traces of metallic impurities in crystalline substances that have the power of emitting light after exposure to light. The absorbed rays, instead of being changed into heat, are transformed into light of a different color, emitted by the substance in addition to the usual colors. Such a substance is a light transformer, inasmuch as it changes the wave length of the rays falling on it. This quality is possessed by all matter to some extent, although it is not always noticeable.

The word "fluorescent" comes from "fluorite," the name of a mineral in which this quality was first noted. The phenomenon, as we are familiar with it, is most frequently associated with the transformation of the invisible ultraviolet radiations into the various colors of the visible spectrum. Ultraviolet rays are part of the sun's radiations, but no ordinary matter fluoresces strongly enough to exhibit this quality while in the sunlight. Human skin and the lens of the eye are faintly fluorescent. The skin can be made to fluoresce strongly by coating it with vaseline or a solution of sulphate of quinine—substances that are powerful transformers and are useful as protection against ultraviolet rays. This conversion of invisible light into visible is demonstrated most dramatically in a room that is lighted only by ultraviolet light. In such a room everything on which these rays fall directly will glow with unusual colors. A powerful source of ultraviolet light is

characterized by its bluish-white light. Such sources are the mercury-arc lamp and the argon-gas bulb.

In a room lighted by only ultraviolet light, teeth and eyes appear a bright blue. As false teeth are not fluorescent, they appear black. Naturally blond hair retains its luster, but dyed hair looks sickly. Fluorescent minerals look like ordinary rocks until they are subjected to ultraviolet rays in a dark room. Then ordinarily colorless hyalite appears apple green, green fluorite appears a royal blue, light-yellow wernerite appears bright lemon, willemite becomes green, and calcite becomes red. Lactoflavin, a vitamin essential to life, glows with an intense yellow light. Some substances may continue to glow for a time after the source of light has been removed and are temporarily phosphorescent, but the invisible rays at the other end of the spectrum (infrared) will immediately quench any such afterglow.

Wood Finishes

Like marble, woods do not display their most attractive colors until they have been smoothed and polished. Some methods of wood finishing are described herewith.

Lacquer. Made from the sap of the tree *Rhus vernicifera*, to which dyes or pigments are added, lacquer is brushed on in successive coats. Each coat is ground down with emery flour or some other similar abrasive. Sometimes as many as 16 coats are applied, each coat being dried slowly in a dark, moist place. The final polish is obtained by rubbing with pulverized deerhorn.

"French Polish." After the surface of the wood is smooth, a diluted solution of shellac in alcohol is applied with a pad of stocking material. When that is dry, another coat is applied. This process is repeated until the desired luster is obtained. Then, the same pad being used, the surface is polished with a very little linseed oil. After it has stood overnight, it is again polished with oil. A unique, soft sheen results.

Transparent Finish in Natural Color. If the wood is open grained, a filler is applied, to provide a perfectly smooth surface. One filler is a stiff paste of special varnish and powdered quartz. It is applied across the grain and the surplus is wiped off. When this

has become hard, it is sandpapered and dusted. Varnish is applied (rubbing varnish if it is to be rubbed). Three or more coats are applied, each being allowed to dry for 24 hours or more. After each coat is dry, the surface is rubbed with powdered pumice stone and water or oil. A final polish is obtained by rubbing with a felt pad, rottenstone, and oil.

Staining. A variety of materials can be used for staining, such as water, oil, spirits, acids, etc. In this connection it is interesting to note that the color of mahogany is naturally a pale yellow, although for so long a time this wood has been stained red that we now always think of it as a red wood. Some cheaper woods are stained to imitate rarer ones. After staining, the surface can be varnished or rubbed.

Graining. This is an imitation of the color and figuration of rare woods that is produced on the surface of cheaper kinds. Ready-made colors and rollers can be obtained for this work, but an experienced grainer would get the effects by a freehand procedure with combs, rags, etc.

Wax Finishing. Some years ago the material used for this process was beeswax heated and dissolved in turpentine; or the dry, powdered wax alone was spread on. Now, after the stain and the varnish have been applied, a manufactured wax is rubbed on. Some such wax products require no rubbing.

Fuming. Formerly this effect was accomplished by exposing the wood to strong ammonia fumes for a long time. At the present time, various chemical stains are brushed on. The following acids are used: tannic, pyrogallic, chromic, picric, acetic, nitric, hydrochloric, and sulphuric. The following alkalies are used: potassium bichromate, potassium permanganate, copper sulphate, ferrous sulphate, ferric chloride, chromealum, and manganese sulphate. After the surface has been fumed, it is finished as may be desired.

Concrete

Concrete is currently colored by staining, by mixing with colored aggregates, or by mixing with dry colors. It can also be painted with specially prepared paint.

Stains are applied with a brush or are sprayed on. Some of the

stains used are ferrous sulphate dissolved in boiling water for buff color and copper sulphate for green.

Aggregates include bits of colored terra cotta, stones, ceramic products, and glass. The aggregate is exposed by treating the surface with acid.

When dry colors are used, they are first thoroughly mixed with the dry cement. Sand and water are then added. A gray cement will produce darker colors. White cement is preferable. White cement with yellow or brown sand will alone produce a cream, yellow, or buff concrete.

The dry colors used in this work are

Blue: Ultramarine blue.
Browns: Burnt umber, brown oxide of iron.
Buff: Yellow ocher or oxide.
Grays: A small amount of manganese black, black iron oxide, Germantown lampblack.
Green: Chromium oxide or a mixture of yellow oxide and ultramarine blue.
Pinks and reds: Red oxide of iron.

Photography

There are over 40 methods of making colored motion pictures. One or more exposures may be made on one or more films through one or more lenses, covered by one or more or no color filters.

In the beginning, the emulsions used on photographic plates and films were sensitive only to the blue and the ultraviolet light waves. The picture obtained with them showed dark and light values that did not correspond with what was seen. Now, however, a picture by photography can be obtained in which the relative brightness of the colors closely approximates what is seen when the objects are viewed directly. In other words, films are now made with emulsions that are sensitive to light of all wave lengths. By screening the film from all light except that which creates the sensation of red, such color can be photographed separately. By the use of appropriate screen, each color can be individually photographed and the relative degrees of intensity are accurately recorded. Such screens are called "color filters." A color filter may be one piece of colored glass or it may be two pieces of colored

glass, with a strip of dyed gelatine between them, cemented together. The glass is perfectly flat and the color is spectroscopically correct. After many variable factors have been provided for, the film is exposed and processed. By one process, three balanced exposures of the same subject are made—one through a red filter, one through a green filter, and one through a blue filter. Thus the color proportions of that subject are recorded on three separate black-and-white negatives. A positive transparent print is made from each negative and dyed with a color that is complementary to the color of the taking filter. When these transparent colored positives are superimposed in register, a picture in color is produced that can be viewed either by transmitted or by reflected light.

In the case of motion pictures or a still picture of a moving subject, all the recording must be done at one time. This can be accomplished with one lens or a group of lenses. The light can be split by prisms or reflectors and distributed to three separate films, or to one film that is differently sensitized on each side, or to two or three superimposed films variously transparent and variously affected by light of different wave lengths. Most commercial natural-color photography of still life is usually made by separate exposures on separate plates with separate color filters. For amateur color photography a film is available that can be used in an ordinary camera without a filter and that requires but one exposure. The film can be returned to the manufacturer for processing or can be processed by the photographer. One method provides for three or four positive transparencies which, in the chemical process, develop color. These very thin colored transparencies are stripped from the supporting film and superimposed in register on a white background, giving the effect of a full-color print. Doctors and biologists find color microphotography useful in the study of germs, etc.

The Technicolor Monopack process, which permits the use of a standard camera for color photography with a single master negative, has been perfected to a point where it is satisfactory for both indoor and outdoor photography. In the laboratory, color separation negatives are made from the master negative for use in preparing the release prints.

Eastman Kodak Co. provides a film called Daylight Koda-

chrome for use in daylight and Kodachrome Type A for use with Photoflood light. This single film supports three emulsions, each separately sensitive to blue, green, and red. After the exposure is made, the film is processed in the laboratory in such a way as to make a positive out of the negative. The film is then taken through a series of special developments, bleaches, fixings, and washings and eventually emerges as a full-color positive transparency. The steps in this process are (1) change of negative to positive; (2) development of the positive image in blue-green color developer; (3) bleaching to destroy the blue-green dye image in the two top emulsions (leaving it in the lowest) and reconversion of the silver to halide; (4) reexposure of the film to the light and redevelopment of the two top emulsions in magenta color developer; (5) bleaching to destroy the magenta dye in the top emulsion and reconversion of the silver to halide; (6) reexposure of the film to the light and development of the top emulsion with yellow color developer; (7) removal of the silver from all three dyed layers, leaving a color picture without silver grain.

The red-sensitive emulsion is next to the safety supporting film, the green-sensitive emulsion is on top of it, and the blue-sensitive emulsion is outside. When the processing is completed, the yellow image appears on the outer layer of emulsion, the magenta image in between, and the blue-green image on the bottom layer.

If Type A Kodachrome is used in daylight, an orange filter must be used to compensate for the excess of blue light. If regular Kodachrome is used with Photoflood light, a suitably corrected blue filter must be used to eliminate the excess of red and yellow light.

The first photograph in color to be transmitted by radio was taken by Capt. Henry Karlin of the U. S. Army Signal Corps. It was of Prime Minister Clement R. Attlee, President Harry S. Truman, and (then) Generalissimo Josef Stalin at the Potsdam Conference in August, 1945. The picture was made in one shot on three negatives. Three separations were made — one for each of red, yellow, and blue. The black-and-white positive prints were sent to this country by radio. Plates were made from the prints and a full-color reproduction appeared in the papers. Colored pictures had been transmitted by wire before but not by radio.

Printing

There are three general processes of printing, whether in color or otherwise. A plate, usually one of metal, receives the ink and deposits it on paper in each case. In the first process, the ink is deposited on parts of the plate that are in relief (letterpress). In the second process, the ink is deposited in parts of the plate that are below the surface (intaglio). The distribution of ink on the plate in the third process depends on differential surface tension (planiographic). The first process is used for line etchings and half-tone reproductions, the second for engravings, and the third for lithographic reproductions.

About 75 per cent of all printing is done by the first, or letterpress, method. The printing area is above the nonprinting area of the plate and is produced by photoengraving. The pattern of a line drawing is reproduced photochemically on a sensitized metal plate (copper or zinc) by one or another process. Nitric acid solution eats away (etches) areas corresponding to blank portions of the design, leaving corresponding black areas intact. The resultant relief image is inked and brought into contact with paper or some other absorbent surface, producing a print of the original design. All parts of such a print are of one color and of the same degree of intensity of such color.

In reproducing such variations of color intensity and such various degrees of lightness and darkness as are found in photographs and paintings, the half-tone process is used. This process is exactly the same as the line-engraving process described above, except that the pattern is photographed through a fine screen, which breaks up the tones into series of dots of various sizes. If the original is in color and it is desired to reproduce such colors, a separate plate is prepared for each color. A fairly accurate reproduction of a full-color picture can be produced with four plates—one each for red, yellow, blue, and black. The most exact work might require a separate plate for each color of the spectrum and for black, as well. The process is as above and the plate for yellow is obtained by photographing through a blue filter, for red through a green filter, and for blue through a red filter. The plate for grays is obtained through an amber filter. The screen through which the photo-

graphs are made is rotated so that the dots of each plate will not exactly coincide with those of the others. The proper yellow ink is applied to the plate for yellow and a print is made. Blue is printed over yellow in register, red over these, and black over all three. The colors which are ordinarily used in this connection are lemon yellow, magenta (a purplish red), and cyan (a blue-green). Inaccuracies of the mechanical process can be adjusted to some extent by supplementary hand etching, altering the size of certain dots as may be required. When many reproductions are needed, duplicate plates are made from the originals by the stereotype or the electrotyping process. This permits any number of machines to print the same picture at the same time.

Effects similar to those of half-tone can be obtained without using a screen when the artist draws with a suitable pencil on a specially prepared hard-grained paper. Yielding plates of various compositions are used to a limited extent in printing by letterpress on metal and similar hard surfaces. Woodcuts and linoleum cuts are produced from plates of these materials cut by hand and may be printed in any number of colors.

In the second process, the printing area is below the non-printing area. The image may be imposed on copper or steel plates by hand or by photography. Depressions below the surface are etched by acid or cut by hand. The cut holds the ink and the surplus ink is removed from the surrounding flat surface. Paper or some other material is brought into contact with the plate while damp and is subjected to pressure. The ink is transferred from the depressions in the metal to the paper and sinks into it or stands up on the surface (embossed printing), according to the qualities of the materials. Such engraving is limited to line work but the printing may be done in colored inks. Stamps, currency, etc., are printed by this method. Different areas may be printed in different colors by separate plates, but the colors are not mingled.

An image with variations of light and shade and color can be reproduced by rotogravure printing. The copper-plated cylinder is etched with a series of uniform cells, or depressions, and the image is transferred by a photochemical process and broken up by the cell formations. This process involves several operations. In printing, the cylinder is flooded with ink and the surplus ink

is removed from the relief, nonprinting areas by a thin steel knife. Rotogravure is commonly employed in newspaper-supplement printing.

In the third general process of printing, the printing and the nonprinting surface are on the same plane; there are no depressed or relief portions. This process is known as "lithography," because the plate was originally a block of stone. Stone is still used, but in general commercial practice zinc or aluminum plates are now used. The design to be printed is photochemically transferred to the plate. The portions bearing the design repel water but will take and retain greasy ink. The rest of the plate is kept damp with water and does not attract the ink. In genuine lithography, a fine-grained stone is used by the artist on which he draws the design with a pencil or a stick of material that has a greasy base. For the sake of visibility, the artist generally uses a black pencil on a white or a light-colored stone. If the artist is transferring a drawing previously made on paper to the stone, he is required to draw it in reverse, so that the print will correspond to the original. He can accomplish this with the aid of a mirror. In commercial practice the zinc or aluminum plate is grained as required and the design imposed on the plate by photography or by hand. The plate is ready when the printing areas will attract only ink and the nonprinting areas only water. A separate plate is made for each color required. The most subtle gradations of light and shade can be effected by this process. There are other methods of printing and variations of each method, as well, but our purpose here is simply to outline the use of color in printing, along with its use in various other fields, to illustrate the part that color plays in our civilization.

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PART FOUR

Guides to Use of Color

10

THE MEANINGS OF COLOR TERMS

WORDS ARE symbols whose function is to transmit thought and convey ideas from one person to another. If any clear thought or definite idea is to be conveyed, the symbols must have the same meaning for both persons. There may be a divergence of opinion in some cases, but there is sufficient agreement for the statements made here to be of practical use. The reason for presenting this part of the book at this point is that the reader may be able more clearly to understand and better to appreciate the parts that follow.

The more common terms used in speaking of color and their meanings are the following:

COLOR. (Spelled "colour" by the British). Webster's New International Dictionary states that it is a property of visible phenomena, distinct from form and from light and shade, depending on the effect of light of different wave lengths on the retina.

The colors presented in the solar spectrum are red, orange, yellow, green, blue, and violet. The extended meaning of color, as we are concerned with it, includes any visual sensation that we experience aside from form. Thus purple, russet, citrine, slate, vermilion, carmine, plum, sage, buff, brown, black, and white, besides hundreds of others, are colors. In analyzing and describing any specific sensation, unless a well-known name is ready for it, we use the name of the basic sensation and qualify it with appropriate adjectives and adverbs.

The term "color" is also commonly applied to any substance that effects such sensations, although the more correct term in this connection would be "pigment," "colorant," or "coloring matter."

Every color has qualities of hue, value, and chroma.

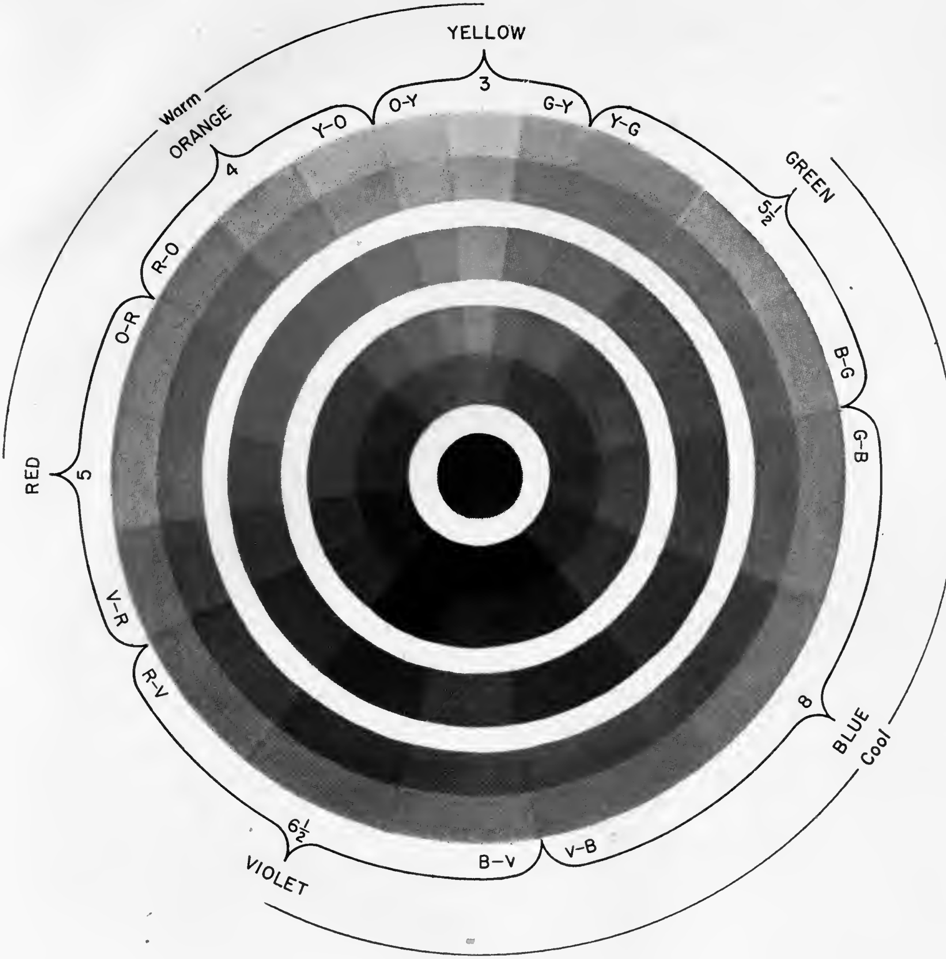
HUE. Hue refers to the basic sensation. For our purposes it refers to the colors exhibited in the solar spectrum. Hue thus refers to the visual sensation produced by light according to its wave length. The term "hue" does not include any quality of color except its relation in the spectrum.

VALUE. Value, in relation to color, is synonymous with luminosity, brightness, lightness, brilliance, or darkness. In the spectrum, yellow has the highest value (it is the lightest of all); blue-violet has the lowest value (it is the darkest of all). The other colors follow in order of value according to their relation to these extremes, as is shown on the color wheel. Value is determined by making comparison with a graduated scale from black to white. Under certain conditions, a certain yellow might appear more luminous than white and a certain blue might appear darker than black; for practical purposes, however, black and white represent the extremes of value.

The natural order of value of color is established in the spectrum. Thus yellow-orange has a higher value than orange, orange than red-orange, etc. In any harmonious use of color these relations must be observed.

In connection with pigment, any color loses brilliance in proportion to the amount of other color lower in the scale that is added to it; any color gains brilliance in proportion to the amount of color higher in the scale that is added to it. Any mixture of color pigments involves a loss of chroma. Thus red added to orange reduces the value and chroma of the orange. Yellow added to orange increases the value of orange and reduces its chroma. A maximum value is obtained with color by adding the most brilliant yellow to it, but there is a limit to the degree of brilliance that a color can attain by this method. The limit is reached just before it fails to be recognized as a distinct color. This is related to the particular color's distance from yellow in the spectrum. Thus yellow can be added to blue for brilliance only up to the point just before it becomes blue-green, at which point it is no longer blue. More yellow can be added to green than to blue, etc. The blue-violet, which is the complement of yellow, cannot be made more brilliant by the addition of any amount of yellow without losing its identity.

Changes of value can be effected also by adding black or white to a pigment. White increases and black decreases its value. White produces a tint and black produces a shade. The limit is reached before a color loses its identity and appears either black or white. With the addition of black or white there is no actual change in



YELLOW
3
O-Y
G-Y
Y-O
Y-G
Warm
ORANGE
4
GREEN
$5\frac{1}{2}$
R-O
O-R
B-G
G-B
RED
5
V-R
R-V
8
BLUE
Cool
$6\frac{1}{2}$
VIOLET
B-V
V-B

the purity of a color, but the existing purity becomes more apparent with a certain amount of white added and less apparent with black added.

CHROMA. Chroma refers to the purity of a color. It is synonymous with strength, saturation, intensity, vividness, or definiteness. It indicates the extent of adulteration, if any, with any other color or with black or white. The greatest purity, or the highest chroma, is as presented in the spectrum; the lowest is just before the color loses its identity and becomes gray. Thus the blue of highest chroma has in it no trace of red, yellow, black, or white.

TONE. Tone refers to a general appearance of color. An area of color in which there is little or no gradation of hue, value, or chroma is said to have or to be a flat tone. A tint is said to be a high tone and a shade, a low tone. A color may be said to have a pleasing tone or an even tone, etc. One may say that he does not like the tone of a color and refer to various qualities. When a color or a composition is increased in brilliance or purity, it may be said to be toned up and, when these qualities are reduced, to be toned down.

WARM AND COOL COLORS. Colors that are associated with cool things in nature, such as the sky, water, snow, ice, etc., are said to be "cool." Some grays, blues, greens, white, etc., are cool. Colors that are associated with warm things in nature are said to be "warm." Most colors containing a large amount of red or yellow are warm colors. There are degrees of warmness and of coolness. Dark red-orange is considered warmer than light red-orange and light blue is considered cooler than dark blue. Greenish yellow or reddish violet in greatest purity is not definitely either warm or cool. Each may appear somewhat warm in a cool situation or cool in a warm situation. Generally a color is as cool as it is blue and as warm as it is red.

TINTS AND SHADES. As has already been noted, a tint of any color is produced by the addition of white; a shade is produced by the addition of black. Accordingly, a tint is lighter and a shade is darker than the original.

BLACK AND WHITE. Black and white are distinct visual impressions, but they are not received from the solar spectrum and so are not colors in the sense that red and blue are. Nevertheless, black

and white are important factors in the application of color and are classed as colors in connection with pigments, dyes, and visual impressions.

Gray. Gray is either a mixture of black and white (no hue) or a mixture of complementary colors. The British spelling of the word is "grey."

Complementary Colors. Any colors are said to be "complementary" if a mixture of them produces a neutral gray. They are usually found opposite each other on the color wheel. Two colors are complementary if their combination embraces all the sensations of the solar spectrum. They are any two colors that are most unlike each other.

Neutral. When no color is predominant or distinguishable, or when the predominating tone is gray, the effect is said to be "neutral."

Analogous Colors. Colors that are related are called "analogous" colors. They are not contrasting colors and are in close proximity to each other on the color wheel.

Primary and Secondary Colors. A primary color is one that is unrelated to and not produced by the mixture of any other primary colors. A secondary color is one that has been produced by the mixture of two primary colors. A tertiary color is one that is produced by the mixture of three primary colors. A certain green paint can be produced by mixing primary yellow pigment with primary blue pigment; that green is a secondary color. But it does not necessarily follow that every green is a secondary color. It is doubtful whether viridian green can be produced by the mixture of any two primary colored pigments. It may or may not be possible to reproduce exactly spectrum green by a combination of blue and yellow light. Some consider that each separate color in the rainbow is a primary color and that any colors not found there are secondary. In paints and with light it is possible to produce certain reds, blues, and yellows from combinations of greens, oranges, and violets. In such cases the reds, blues, and yellows would be secondary, because they had been produced from mixtures of other colors. Thus various colors may be considered primary or secondary, depending on their origin. From a painter's point of view, crimson lake, gamboge, and prussian blue or cadmium red, cad-

Violet shade | Blue-green shade | Orange-red shade

These colors differ in HUE but little in value

Red tint | Red tint | Red shade

These colors differ in VALUE but not in hue

Yellow-orange tint | Orange | Red-orange shade

These colors differ in HUE, VALUE and CHROMA

mium yellow, and ultramarine blue might be considered the primary colors. The physicist might say that the primary colors are red, green, and blue-violet; the physiologist, that they are red, yellow, sea green, blue, black, and white. The painter's choice would be those colors that he believes are unable to be produced by any mixture of any other paints. The physicist would choose those colored lights that no combination of other colored lights could produce. The physiologist would choose those colors that do not look like any other color or combination of colors.

Advancing and Receding Colors. The advancing colors are those reds, oranges, and yellows that seem to be coming toward the observer. They are aggressive, warm, or stimulating. The receding colors are those blues, greens, and violets that seem to lead the eye away. They are usually restful.

Chromatic. Chromatic refers to the presence of color. A chromatic arrangement, for instance, would be an arrangement effected with colors.

Achromatic. Achromatic refers to the absence of color. An achromatic effect would be one produced without color.

Monochrome. Monochrome refers to one color alone in degrees of value and/or with black, white, silver, or gray.

Polychrome. Polychrome means having many colors. It is the opposite of monochrome.

Color Dimension. Color dimension is analysis and definition in terms of hue, value, and chroma.

Acknowledgment is given to the following sources of information. See also Part Seven.

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Maerz, A., and M. Rea Paul: "A Dictionary of Color," McGraw-Hill Book Company, Inc., New York, 1930.

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Webster's New International Dictionary.

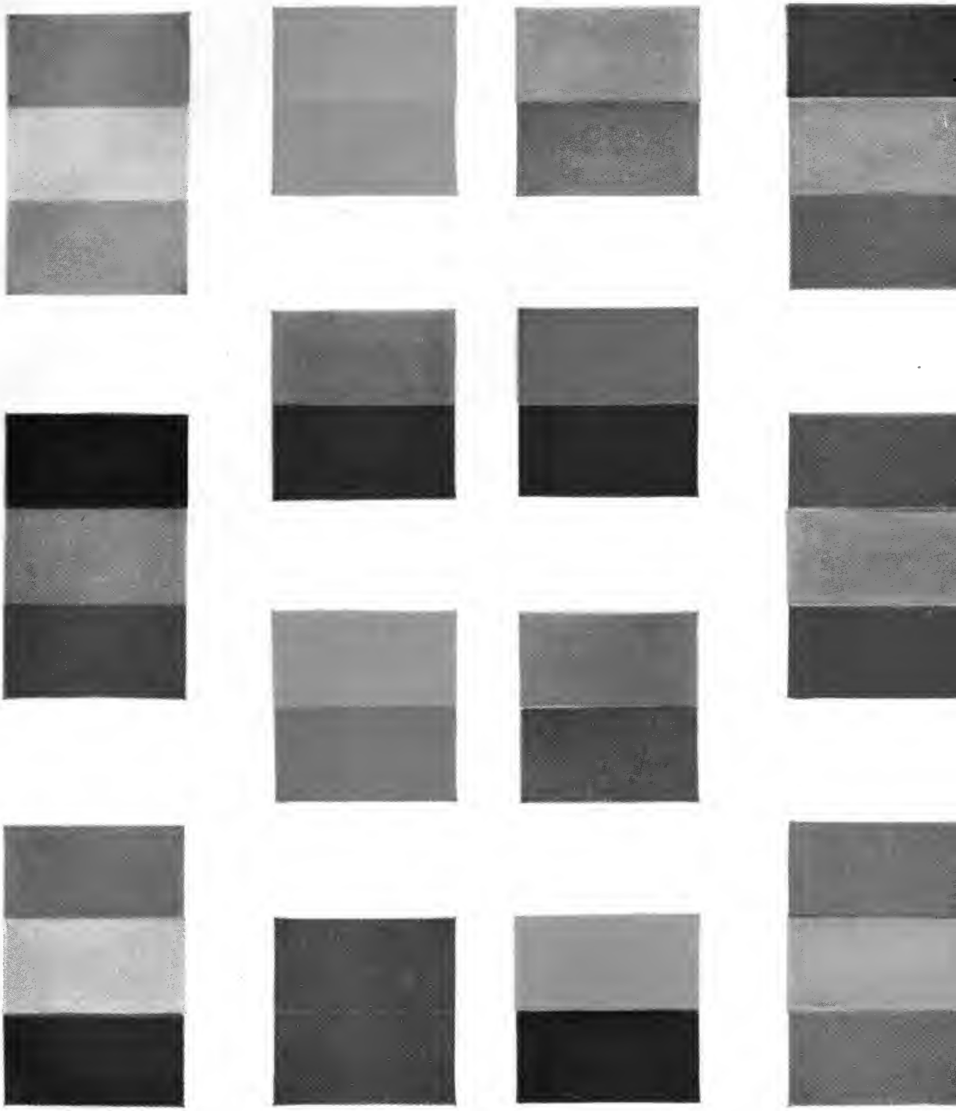
II

HARMONIES AND DISCORDS

Harmony

Any color effects or colors that are consistent with nature and because of this are pleasant to see constitute a color harmony. A color harmony includes unity, consistency, and fitness, as does every other kind of harmony found in life. In any harmony we are safely guided by nature. It will be noted that a scene is either cool or warm, not half and half, and that it is related to the actual temperature. A winter scene is full of cool colors; if any warm color is present at all, it is introduced in comparatively small amounts, thus by contrast emphasizing the coldness, so that the effect is satisfactory. A composition is not harmonious if it is indefinite or unsettled. It may or may not have elements of contrast, but to give an effect of harmony it must be predominantly either warm or cool.

All colors can be used to produce harmonies or discords. No color is universally good or bad. The roots of all color are in the solar spectrum, and the complete spectrum comes from and can be returned to white light, which is neutral. A mixture of paints of spectrum colors produces a neutral gray. It is gray and not white because by its nature all paint absorbs some light. Wherever any element of the spectrum is lacking, neutrality is incomplete. That which is complete is harmonious. Thus a design, composition, or ensemble of color is most complete and harmonious when it includes all the elements of the spectrum. From this we deduce that certain colors are complementary to each other, the one added to the other equaling completeness and neutrality. Their sum includes all the sensations of the spectrum. A certain green and a certain red may be complementary to each other, while other greens and reds are only near complements. Probably because of his own imperfections, man finds sympathy in other things that fall somewhat short of perfection and near-complements can often be combined with pleasing effect. True complements afford the



Monochrome | Analogous | Complementary | Triad

greatest possible contrasts in hue; that is, the color that is complementary to orange is as different as possible from orange.

The color wheel, a device that is intended to indicate at a glance such differences, represents a band of the spectrum bent into a circle whereon the complements are directly opposite to each other. The wheel in this book presents the colors in the same proportions as they appear in the spectrum. An analysis shows them to have the following approximate proportions: yellow 3, orange 4, red 5, green 5½, violet 6½, blue 8. Colored light combined in these proportions produces white light. To produce such absolute neutrality with paints of these colors, the proportions must be reversed, because the nature of paint is opposite to the nature of light. Blue-violet light gives the least light, whereas blue-violet paint absorbs the most light. The proportions of paint of spectral hues to produce neutrality when mixed would, therefore, be approximately yellow 8, orange 6½, red 5½, green 5, violet 4, blue 3. However, a composition embracing these colors will be most harmonious when the colors show the proportions that exist in the spectrum.

The color wheel presented by Faber Birren in his book "The American Colorist" has the following colors: yellow, leaf, green, jade, turquoise, blue, violet, purple, magenta, red, orange, and chrome. For reasons that he explains, the blues of his wheel occupy a smaller proportion of the total space than they do in the wheel shown in this book.

If we assume that each color has its greatest intensity at the center of its respective part, the arrangement on our wheel indicates that red and a greenish blue are complementary, as are orange and a blue that is slightly violet, yellow and a bluish violet, green and a reddish violet, blue and a reddish orange, violet and a yellowish green.

Triads are three colors that, in combination, represent the whole spectrum and are useful in producing harmonies of contrasting hues. Such colors are equidistant from each other on the wheel. The triad that includes yellow of full intensity would also include blue of full intensity and a violet-red.

Completeness, simplicity, unity, and harmony go hand in hand. A single color can be employed to produce a harmony, with varia-

tions of value. This is called a "monochromatic" harmony. Two or more closely related colors can be used to effect an analogous harmony, the degree of harmony in this case being in proportion to the proximity of the colors. Full orange and full green, while they are related by yellow, do not harmonize so well with each other as either of them would with yellow. They are too far apart to be intimate and not far enough apart to contrast most pleasantly.

A very important element of harmony is that of comparative brilliance. The relative brilliance of the colors in a harmonious composition must generally agree with that found in the spectrum. The green of the spectrum is lighter (more brilliant) than the blue and any harmony must correspond with this. Thus a green that appears in combination with a lighter blue does not effect a harmony with it. The spectrum is a standard of color harmony whose related qualities must be respected if any simulation of harmony is to be effected.

The judgment of a harmony is according to the degree of satisfaction and pleasure it gives to the observer. In general, a harmony should result from the observance of the laws and practices of nature, which provide that the product should have variety, balance, rhythm, unity, and fitness. It would be difficult to establish a formula for producing a harmony that would find equal favor with everyone. Individuals vary somewhat in sensitiveness, as a result of associations, environment, training, temperament, and heredity, all of which influence the judgment. However, the variation is relatively small and the information and suggestions given here should at least provide a solid foundation on which the individual can build.

Harmonies can be effected by the use of (1) any one color in different values (shades and tints), (2) any two colors that are complementary or analogous, (3) any three colors that are equidistant on the wheel or any three colors that are analogous, (4) any number of colors, including both complementary and analogous colors, in any number of shades and tints, provided that the relative brilliance corresponds with that of the spectrum. Black, white, gray, glass, gold, silver, etc., do not clash with any colors and can often accompany them with pleasing effect.

For color harmony, Birren recommends that colors be used as follows:

Pure colors with tints and white.
Pure colors with shades and black.
Pure colors with tones and gray.
Shades and tones with white.
Tints and tones with black.

Discords

Discords, which are the opposite of harmonies, are generally unpleasant and cause irritation. They are produced by deviating from the standards of nature. Discords, while they are generally undesirable, can, if used with understanding and judgment, be employed in small amounts in an otherwise harmonious composition to produce delicately beautiful color effects. They are false notes, it is true, but the unexpected (if it is not too violent) has a certain charm for our senses. Discords can contribute that touch of acidity or sourness which sharpens our appreciation of the whole. Discords are never justifiable in large doses, but in small quantities they lend brilliance and vibration and prevent rich harmonies from being too sweet. Nature presents discords in its high lights. The high light on an orange is a rosy red; on a red cherry, it is a pale purple; on a purple plum, it is a pale violet-blue; on a dark-green leaf, it is a broken tint of blue. Many Persian and Oriental art objects owe some of their charm to the proper use of discords. A discord can be introduced in a room by means of a single vase or cushion, to effect a sparkle if that is needed to prevent tameness.

Large amounts of dark red and light blue together are very disagreeable, but a touch of deep crimson in a field of light blue is interesting. Likewise a large mass of weak purple with strong red is hideous, but a harmony with red (red and green-blue for instance) can be enlivened with a touch of light purple in the blue area. Yellow-brown is harmonious with deep blue but with pale blue it would be discordant. Any combination of discordant colors appears dirty. Greens and browns are a common cause of dirty effects, because they are about halfway up the scale from dark to light and a mistake of natural order is not so obvious. Tints of

blue, purple, and violet must be supported by lighter yellows, oranges, greens, and reds or they will appear unpleasant. To be pleasing, shades of yellow, orange, and brown must be supported by darker reds, purples, violets, and blues.

Acknowledgment is given to the following sources of information. See also Part Seven.

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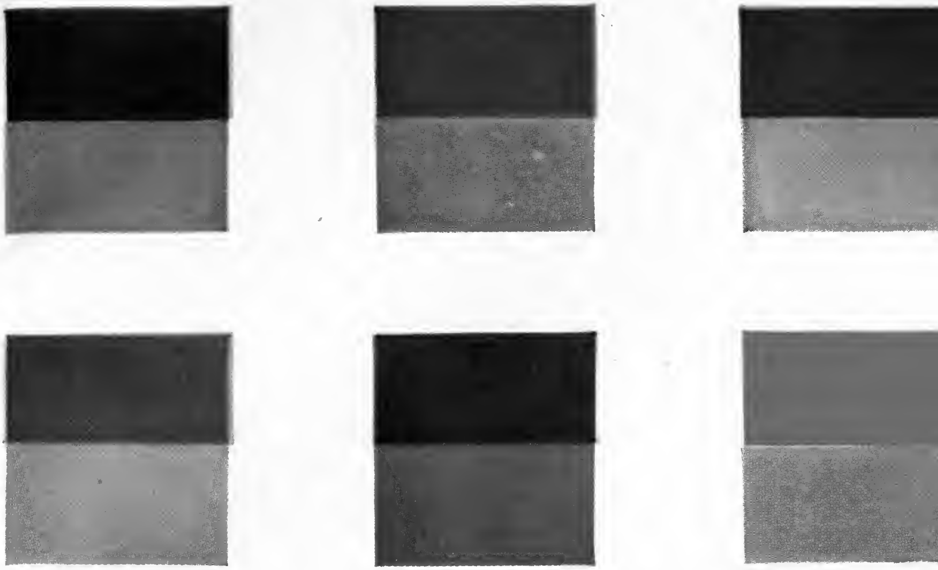
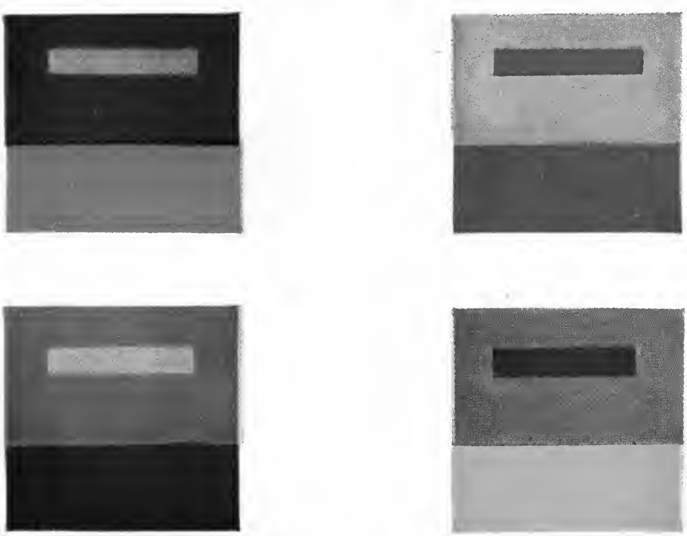


Discords (above)
Harmonies including a note of discord (below)



12

COLORS IN COMBINATIONS

The general preference is for pure color to be used sparingly and as an accent to larger masses of mixed color around it. There are infinite numbers of harmonious color combinations, all of which have some affinity with nature. A group of colors appeals to us as harmonious because their effect strikes within us a chord of sympathy, and that chord of sympathy has been inherited from generations of our ancestors who have been observing the color combinations of nature.

Pure color is not common in nature and even the tiniest fragment of color will usually be found, on careful examination, to include gradations of hue, purity, and brilliance. Every aspect of nature presents harmonies of like or contrasting colors. Everyone should cultivate his ability to recognize them by studying nature. It may be possible for man, working in accord with natural laws, to produce more brilliant and fascinating harmonies with color than any that have been found in nature. However, such cleverness has doubtful value in any interpretation of nature or in the creation of anything that is other than a novelty.

The most pleasing effects are achieved in harmonies of a few colors, but a harmony of this sort requires a more careful selection than a harmony produced with several colors. Colorful and interesting grays are produced by combining complementary colors in various proportions with or without black and white. Such grays are lively and not flat. A thin fabric over a fabric of its complementary color makes an interesting gray effect. Gray cloth woven with alternate threads of complementary colors is more interesting than one woven from black and white threads. Shadows from strongly colored lights appear to be somewhat complementary to the light. The most common complementary combination in nature is blue and orange, and there are few persons who are blind to these colors. Blue and orange have a wide range of effects. Red-and-green combinations have a more limited range of effects

and they are more dependent on the help of grays. Yellow-and-violet effects, which are delicate and elusive, can be indefinitely warm or cool. Orange and turquoise is a good combination that is warm and bright, while leaf green and violet is a good combination that is cooler.

The use of adjacent colors makes a rich, deep, and lively effect. Blue water is a combination of blue-green, blue, and blue-violet. Blue sky is a combination of green-blue, blue, and violet-blue. In trying to determine what hue an object has, it is helpful to hold up a piece of white paper between it and the eye. The paper appears gray and this gray intensifies the color seen beyond, making it appear more definite.

Pleasing effects can be obtained with one color and neutrals, such as (1) strong contrast of purity and brilliance, together with black and white; (2) slight contrast over all, every part quiet; (3) graduated purity and brilliance to the point of interest.

Complementary colors by contrast intensify each other, as in a scarlet rose with blue-green leaves. Such combinations seem to struggle and waver. If actual slow motion is given to such a combination, an effect of flamelike brilliance is produced (as in banners and dancers' costumes). To ascertain what the complement of a color is, one can look at it steadily under a strong white light for 30 seconds, then look quickly at a pure white surface. The afterimage seen there, which develops to full intensity in 3 seconds, is the complement of the original color. This image loses strength after 3 seconds.

A flat area of color is tiresome, but it can be relieved by gradations of any or all qualities. Surface texture can greatly contribute to the "life" of color. Painters model their paints on the canvas to create surfaces that reflect light with pleasing complexity. Brilliant colors are not necessarily crude and gaudy but may be wholesome and desirable. The presentation makes them what they are. Black, white, and grays are great harmonizers. A colored spot or initial on a white page with black type is most pleasing when it is of about middle value (halfway between black and white). In this connection orange-red is very satisfactory. Blue-green shutters are attractive on a white house.

Triads such as blue, yellow, and violet-red, when they are properly combined, are sumptuous. These combinations were used effectively in architecture by the Egyptians and by the Greeks and by the Gothic stained-glass makers, as well. Such combinations can be given greater depth and richness by veiling the whole with a light-yellow glaze. In the case of architecture and stained glass, the sunlight furnishes this effect. Red-orange, yellow-green, and blue-violet are not so pleasing when presented together in greatest purity. Yellow-orange, red-violet, and blue-green together produce a most unusual artificial effect.

The color of an object attracts the attention and holds it, and the pleasure that it gives is affected by the arrangement of the areas and the relations of all its qualities. The colors of a design should be in harmony with each other and with the subject. Such consistency and unity contribute to harmony. Designs predominating in curved lines convey a feeling of joy and lightness; those in straight lines, a feeling of seriousness; and those in zigzag lines, a feeling of violence or unrest. So, to achieve the greatest success, the appropriate colors must be arranged appropriately. Black is more pleasing when it is presented with two brilliant colors than it is with one that is brilliant and one that is dull. White is more pleasing when it is accompanied by one brilliant and one dull color than it is with two alike.

Good examples of colors combined with black and white are as follows:

Black: With orange and red, orange and yellow, red and yellow, red-violet and yellow, yellow-green and yellow, yellow-green and orange.
White: With red and blue, orange and blue, red and blue-violet, yellow and blue, orange and blue-violet, yellow-green and blue, yellow-green and blue-violet, yellow and blue-violet.

An orange area appears to be closer than it actually is and a blue area, farther away. Other colors have this effect as they approach orange or blue. Thus, as has been previously noted, warm colors are said to be "advancing" and cool colors, "retreating."

Some contrasting combinations are more visible than others

at a distance. The following combinations are arranged in the general order of their visibility from a distance:

1. Black on tint of yellow.
2. Black on tint of yellow-orange.
3. Tint of yellow on dark blue-violet.
4. Tint of orange on dark blue-violet.
5. Dark blue on white.
6. Dark red on white.
7. Black on white.
8. White on dark blue.
9. White on black.

It must be understood that the contrast in brilliance is more important than that of hue. Estimates on the visibility of color combinations differ because the brilliance of the colors considered is not constant. It is agreed that black on light yellow is more visible than black on white, because yellow can be more brilliant than white. One of the least visible combinations would be red on green-blue of equal brilliance.

Of all the colors, red has the greatest attraction value, although in some circumstances strong yellow is more effective in demanding attention. Consequently, red dominates about 75 per cent of the space used in color advertising.

A blue, a yellow, and a gray may all be of the same brilliance (photometrically), yet the blue will appear darker than the gray and the yellow will appear lighter than the gray.

Effects produced by gradation are more refined than those produced by contrast. The details of a design should be smaller, purer, and brighter than the general surrounding areas. The whole may be given unity by permitting one color to predominate or by relating all the colors and enclosing the whole in a contrasting frame. An effective practice is to surround an area of flat color with a series of outlines of graduated brilliance inward or outward. The outlines may be of the same hue or of other harmonious hues or of grays.

Grays or neutral areas increase the apparent purity of adjoining areas. Black and white are most effective when the areas they occupy are either great or small in comparison with the colors

that they accompany; that is, large areas of black or of white are most effective with small areas of color, or vice versa.

The Munsell Color Company, Inc., in their booklet "Directions for the Use of the Charts in the Munsell Book of Color," offer the following suggestions for obtaining color harmony:

1. Avoid the use of more than two or three hues. Several colors from a single hue chart are very effective when properly used. If two or more hues are used, choose either closely neighboring hues in sequence or hues that are opposite on the hue circuit.

2. Balance dark colors with light colors. Small areas of high value will balance much larger areas of low value.

3. Avoid the overuse of strong colors. Small areas of strong chroma will balance large areas of weak chroma.

Tints and shades are not good together. The eye likes clear-cut form, contrast, and variety. The warm hues are best for shades and harmonize best with black, while the cool hues are best for tints and harmonize best with white.

Some good examples of color combinations are these: Light green-blue on darker violet-blue, separated by white or gold; black on golden brown; light green on dark blue; white, scarlet, and black, supported by a greater quantity of less brilliant red, yellow, and blue on a gray-blue ground; lemon yellow and silver; grayish yellow and white; dark violet-red and darker blue; dark blue-green with less and lighter orange-red, a smaller amount of black, and a still smaller amount of gold or silver; red-violet (purple) and grayish green (sage), outlined in gold on a dark-blue ground; dark red, grayish light yellow, and a small amount of light blue on a dark-gray ground; light yellow-green on dark red-orange; dark blue-green and light yellow-green on dark red (crimson); light green-blue on dark gray-blue, with spots of white and gold; yellow-green and grayish orange, outlined in gold on a dark grayish-green ground; red-brown, orange-red, red-orange, orange, yellow, orange-yellow, with tints and shades of green; dark gray-blue, yellow-brown, with various greens and blues and some black; gray-violet, deep pink, brownish gray, bluish green, orange, and grayed orange; turquoise blue, grayed violet, blue-green, and light red-violet.

In the following examples of good color combinations the approximate proportions are indicated:

Blue-green 60, white 20, green-yellow 8, orange 6, purple-brown 6.
Blue 35, yellow 30, white 15, dull red 10, black 10.
Blue 60, deep yellow 20, light yellow 10, white 10.
Light yellow 34, green 27, blue 25, red 6, gold 4, black 2, white 2.
Green 36, blue-green 24, yellow 14, red 11, white 10, dull red 3, black 2.
Black 63, yellow 17, green 9, red 4, light red 3, blue 3, white 1.

The color combinations given previously in connection with birds, insects, etc., are good; for Nature is a most reliable colorist. The color combinations found in birds of paradise are very dramatic and useful in modern color schemes. Some of the combinations noted are black and turquoise; emerald green, black, orange, and red-brown; tan, orange, light cream, yellow-green, and black; medium vivid blue and black; orange-yellow, orange-red, light blue, light purple, and greenish black; straw, reddish brown, light turquoise, and black.

The following combinations come from a few military service ribbons: dark blue and gray; orange-red, dark blue, yellow; orange-yellow, dark blue; dark blue, red, green, yellow; red, white, blue, black; red, yellow, blue; red, white, blue-gray; red, white, blue, orange; red, white, and two blues; dark orange, grass green, red, white, blue-black; light orange, red, white, blue, green.

Colored Pigments in Combination

It is as impossible to learn how to paint pictures by reading words as it would be to learn to play the violin by such a method. However, the following notes on some of the qualities, possibilities, and limitations of paint may be of some value to anyone who is concerned about the use of paints.

Pigments absorb light according to their hues, and two or more colors in combination absorb more light than any one of them does alone. Thus any mixture of paint involves a loss of brilliance and purity to some extent. Yellow mixed with blue loses most of its brilliance, adds a little to the blue, and together they produce something that is inferior to either. There is no actual change of color when two pigments are mixed; there is no chemical change;

the resulting effect is an optical illusion. Minute granules of colored matter are held together by oil, etc. In a yellow paint the granules are all yellow, in a blue paint they are all blue, etc. When these are mixed, a synthetic sensation is effected that might appear green. Colors lose some or all of their character when they are mixed. Two or more originally beautiful colors, in combination, may produce a flat, dull, dead, dirty sensation.

If it is desired to effect a green sensation with paint and it must be done with yellow and blue, the paints can be allowed to retain their individual character and force by not being mixed but by being applied to the surface in small spots close together. By this method no loss of brilliance is suffered and the resulting sensation has the force and character of both hues. The French painter, Cézanne, working in this way, produced some very vivid greens. In fabrics, alternating colored threads give the same effect.

It requires a certain amount of yellow in order noticeably to change the hue of blue, but a very much smaller quantity of blue makes a great change in the yellow. Thus a paint is sensitive and reveals adulteration according to its brilliance.

Black added to a color makes it warmer and darker, while white makes it cooler and lighter. Black added to orange makes it appear redder, whereas white makes it appear yellower. There is no actual change in hue in either case, but a change in brilliance. Many capable painters do not use any black paint, as shadows and all other aspects of nature can be perfectly represented by combinations of colors. On the other hand, white is practically indispensable to the artist working in oil, unless he paints thinly—as a water-colorist does—permitting the white of the canvas to show through.

The perception of color in terms of paint requires experience. The experienced painter easily analyzes what he sees and translates his sensations confidently in paint. Thus a certain gray might to the average observer be only that, apparently nothing but a mixture of black and white. The painter, however, knows that he could not reproduce that gray by means of any combination of black and white. To him that gray can be compounded only from the proper proportions of orange vermilion, cobalt blue, and white.

A portrait might be painted with a red and white and black,

but a more satisfactory portrait would include orange vermilion, a crimson, a yellow, a green, a blue, and white. We know that a white cow or a white house is actually white on all sides, but in the sunlight the side in shadow appears bluish and the parts that directly reflect the light appear yellowish. Thus in the artist's painting, the white cow is not white at all, but part yellow and part blue, there being no other correct way of representing it. The ability of artists to recognize the color of shadows has been developed within the last century or so. Before that, all shadows were painted black, gray, or brown.

Several hundred colors are manufactured for artists' use. The names of the colors are no absolute guarantee of their exact hue, as a color of a certain name may vary in hue between one manufacturer and another and also between different batches of paint of the same manufacturer. The following are the names of some colors that approximate the colors of the spectrum: alizarin crimson, cadmium orange, cadmium yellow, cadmium lemon, emerald green, cobalt blue, cobalt violet. These with white might serve for a complete palette, although it is doubtful whether any artist confines himself to the use of these colors alone. There are also various other reds, yellows, greens, and blues that are very useful.

Good painters are unusual persons, endowed with unusual powers and ability. They frequently see things that the average mortal does not notice, because their powers of perception are more acute than the average. The painter's object is not to reproduce anything photographically, but to create a beautiful and interesting composition that will enhance its surroundings when hung and influence its observers as was intended. The finest picture may reflect some real situation or it may be the product of pure fantasy. It may appeal to some and not to others, depending on the many factors that have contributed to the development of the observer.

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13

VARIATIONS OF COLOR APPEARANCE

THE PROBLEM, of producing harmonious color combinations is made more complex by the fact that, while even normal eyes are subject to illusions, many eyes are not normal. However, it is true that most persons receive the same sensations under similar conditions, so a brief consideration of normal aberrations will serve our purpose. Colors in proximity tend to change each others' hues under certain conditions. Gray on a yellow background appears to be bluish; on blue, yellowish; on red, greenish; on green, reddish. Yellow on a blue ground is accentuated. The juxtaposition of noncomplementary colors tends to weaken the chroma of each.

Yellow and green of equal amounts and intensity when placed side by side influence each others' appearance. The yellow is pushed toward orange and the green toward blue. As the yellow is given a greater area, it has greater strength and pushes the green further toward blue proportionately; the limit is reached when the green touches green-blue. When yellow and blue of equal strength are put side by side, the yellow appears tinged with orange and the blue, tinged with violet. As the balance of power shifts to yellow, the yellow loses its tinge of orange and the blue appears more violet-blue. When yellow and blue-violet of any amount are put side by side, they are already as far apart as possible in the color scale and can push no further away. The result is that they intensify each other, each of them appearing more vivid according to the relative force expended. This condition gives each color the appearance of being restless, as if actually surging back and forth where the two meet. These effects can be diminished by separating them or insulating one color from the other with an area of black, white, or gray. The gray may be a mixture of complementary colors or of black and white.

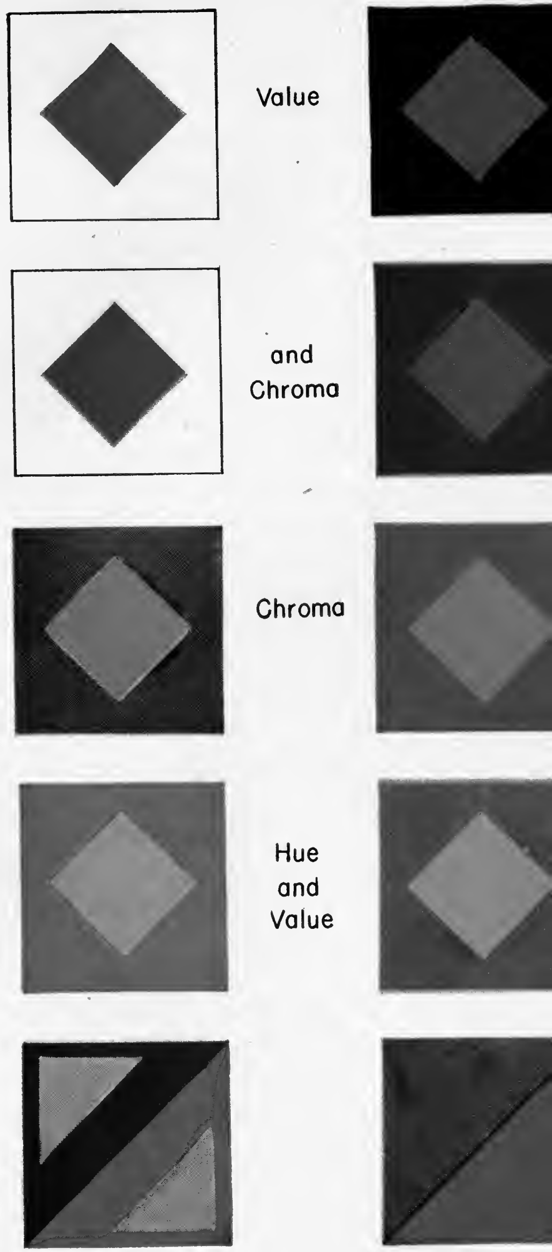
Same color on black and white

Same color on white and shade of same

Same color on grey and shade of same

Same color on colors analogous to it

Vibration of complements and effect on grey



Any large mass of color tends to give lesser near-by masses a tinge complementary to itself. Thus a white statue in a room with green-blue walls would appear to have a pinkish cast. Likewise a gray tree trunk amidst green foliage appears "warmer" than it is. A face that lacks strong color has a more ruddy appearance under the influence of green-blue accessories. Black surrounded by green-blue appears rusty. The larger mass seems to destroy the individuality of the smaller; the stronger engulfs the personality of the weaker and, if resisted, breaks its spirit. This can be overcome by nonresistance. The strongest wind will not break the willow tree, because it bends in harmony with the wind. Likewise if the white statue mentioned is to appear white in the green-blue room, it must be tinted with some of that color. If black surrounded by a color is to appear most black, it should contain some of the surrounding color.

If one half of an orange ground is covered with a strong green pattern and the other half is covered with a pattern of strong purple, the patterns will intensify each other and the ground will appear different under each. Sharp contrasts in brilliance are violent, causing a degree of destruction to color. Any dark color on a light ground appears to be darker, the ground appearing lighter than is actually the case. Dark red would seem to be almost black when seen on a very light-green background. Contrasts of brilliance are effective in small areas for accent, but the larger areas of a composition are more pleasant when they are closer in lightness or darkness. Larger masses are more pleasing when they are brighter and less pure than the accompanying smaller masses. Outlining a lighter color with a darker color emphasizes it and gives it greater brilliance.

Black and white, which are valuable for their harmonizing influence, provide an admirable foil for any color. White tends to lighten and cool adjacent colors and to make them appear stronger and black has the opposite effect.

Illumination affects any situation; the color of the light is reflected from the surroundings. A dark situation calls for brighter and more vivid colors than does a light situation. Adjacent contrasts of hue and value vibrate more under dim light than under bright light. An object seen in a light whose color is comple-

mentary to it appears black or gray. The apparent color of an object is also influenced by the color of the light to which the eye has been recently exposed. When anyone has been working for a while under a yellow light and it is replaced by a white light, all objects tend to appear slightly more violet than they are. The color of translucent material appears more intense when it is viewed by transmitted light than when it is seen by reflected light.

Color intensity does not increase with increased illumination. In fact, color appears more vivid under moderate illumination than it does under very strong illumination; very brilliant illumination can completely rob a substance of its tone color. Red suffers least under ordinary artificial illumination, blue loses much strength, and yellow loses most.

Regardless of what the essential color of an object may be, that part on which bright sunlight is falling in full force may appear to be nearly white. Although the appearance varies under various conditions, a general observation is that objects in bright sunlight have a warm (yellowish) appearance on the light side and a cool (violet) appearance on the shadow side.

The fact that bright sunlight devitalizes color permits and makes desirable the use of saturated colors and strong contrasts under such conditions, if the colors are to have any attractive value. Thus outdoor advertising posters must be garish if they are to be effective in the brightness of the sun. However, on a dull day, when the colors are viewed in their true intensities, the same poster appears unnecessarily gaudy.

In the tropics, where the sunlight is especially brilliant, nature displays the gaudiest colors and the greatest contrasts. In the birds and flowers of the tropics, the most intense colors are seen side by side, but they appear quite pleasing in the bright light. Houses in the tropics are often painted bright yellow, pink, orange, green, or blue and are quite attractive. Likewise native costumes exhibit pure colors with pleasing effect, although the same colors if used in temperate zones would not be so pleasing. In temperate zones, where the sunlight is moderate, owing to the angle of incidence and to haze, broken colors are more common in nature and are used in decoration by man. Far to the north, where the

sunlight is weak and there is much cold and darkness, bright, warm colors are again in order.

All materials seem to be very limited in their capacity to absorb light. Thus a red object is able to absorb all the blue and yellow rays only of a moderate light. Strong sunlight taxes its ability to absorb yellow beyond its capacity and the object appears to be somewhat orange. Depending on the relative positions of the sun, the object, and the eye, the red object may appear white (specular reflection).

You may wonder why, if half of the sunlight is composed of blue rays, it does not make objects appear blue instead of yellow or white. This is due in part to absorption, but more especially to the relative luminosity of the different wave lengths. Most of the sun's luminosity is concentrated in the yellow rays and this concentration far overshadows the greater proportion of blue and red rays present. White paint is about fifty times brighter (more luminous) than black, but a light-colored object in sunshine is several hundred times brighter than a deep shadow.

In bright illumination, the color of a translucent object appears most intense by transmitted light. An example of this is the bright-red appearance of a person's ear and the bright green of a leaf when the light is seen coming through it, as compared to the normal appearance as the sunlight is reflected from it.

An orange and a blue that appear of the same value under high illumination change their apparent values under low illumination, so that the blue appears lighter than the orange. As the sun is going down, reds, yellows, and oranges lose their luminosity first and tend to appear black. At the same time, the greens become gray and the blues and violets retain their color longest. At night all colors tend to approach dark blue or violet-blue. If the moon is low, it may appear reddish through a haze. The sky near by will have a reddish to violet appearance and the foliage will cast deep-purple shadows. A high moon on a clear night appears yellowish white and gives a silvery-gray appearance to the foliage. Moisture in the air may cause the moon to appear greenish.

The color of an object is influenced by the color of the illumination. Thus material that reflects all the light rays will appear white

under white light, red under red light, etc. Generally any color illuminated by a light of its complementary color would appear black. Material that absorbs yellow and blue light appears red under a white light, as does a red rose. The same rose would appear nearly black under a blue or a green light, orange under a yellow light, and grayish red under a red light. In violet light, green appears gray or violet, while in a yellow light it appears a bright yellow-green. Blue under an orange light would appear black and under a blue light, a lighter blue. A red cloth in a blue-green light would appear dark gray or black, with a small surface reflection of blue-green light. Black seems to glow under sunlight or normal artificial light. Similar results are obtained by looking at objects through colored glasses. Through a blue glass a blue object appears bluer, orange is grayed, red is purplish, and yellow is greenish.

Experiments made by the General Electric Co. show that the following effects take place.

Red light on red makes it appear gray.
Red light on orange makes it appear red to reddish gray.
Red light on yellow makes it appear red to red-gray.
Red light on green makes it appear brown or gray to black.
Red light on blue makes it appear black.
Red light on violet makes it appear red-gray.
Red light on brown makes it appear gray-brown.
Yellow light on yellow makes it appear yellowish gray.
Yellow light on blue makes it appear yellow-green.
Yellow light on violet makes it appear yellow-gray.
Green light on green makes it appear gray-green.
Green light on red makes it appear dark red to black.
Green light on orange makes it appear dark orange to light brown.
Green light on yellow makes it appear yellow to gray-green.
Green light on blue makes it appear dark blue to blue-black.
Green light on violet makes it appear blue-gray to gray.
Green light on brown makes it appear brown to black.
Blue light on blue makes it appear blue-gray.
Blue light on red makes it appear dark red to black violet.
Blue light on orange makes it appear light orange to red-brown.
Blue light on yellow makes it appear yellow-orange to yellow-brown.
Blue light on green makes it appear light blue to gray.

Blue light on violet makes it appear lavender to gray.
Blue light on brown makes it appear red-brown to black.

From the above it follows that, by green light, a fine red steak and a cup of good coffee might appear a sickly gray. Under a red light, the celery, milk, and bread would appear pink; the salad brown or gray; lemons red; peas black; peanuts red; etc.

The proper illumination of night clubs and such public places is very important if the customer is to be pleased. A pink light pales lipsticked lips; a green light blackens them and shows up wrinkles; blue light reveals make-up too noticeably; amber light washes out most color. Satisfactory lighting is produced by means of various combinations of these, with consideration of the surrounding reflecting surfaces.

One very important difference between the two most applicable home light sources—filament and fluorescent—is in their effect on color. The white fluorescent lamp emits a greater proportion of blue and green light than does the filament lamp, thus tending to emphasize blue, green, and yellow in interior colors and to tone down red and orange. The filament lamp emits a greater proportion of red and yellow light, thus emphasizing red and yellow and toning down blue and green. These same color alterations are noticeable on foods.

Colored light is usually undesirable for critical seeing, but may be desired for special decorative effects. Colored light is obtained from colored filament or fluorescent lamps or by placing colored glass or gelatins over white lamps.[1]

The mixing of light differs from the mixing of paint in the resultant effect. Any light has a certain amount of brightness, so two lights combined would result in greater brightness. Any paint absorbs some of the light falling on it, so two paints combined would absorb more light and lose in brightness. Thus red, yellow, and blue light mixed in certain proportions produce a maximum of brightness and appear as white light. Any mixture of red, yellow, and blue paint, on the other hand, produces a gray, which has resulted from a triple subtraction of light.

White light can be produced by combining a red light and a

[1] *Illuminating Engineering*, June, 1945, p. 348.

greenish-blue light or orange and cyan blue, yellow and indigo blue, violet and greenish-yellow lights. Thus the combination of complementary lights produces white light but of paint produces only gray paint.

Colored disks arranged in certain proportions can be rotated at certain speeds to produce mixed color sensations. The results resemble similar light mixtures. With colored disks in rotation, the successive subtraction of paint is avoided but the sum of brightness of light is not achieved. A mixture of blue and yellow paint produces a green sensation, while the rotation of disks of such colors produces a gray sensation. Blue and orange paint produce gray, while such disks when rotated produce a violent purple.

Light in passing through colored glass or other translucent matter suffers from absorption. It was noted that blue and yellow paint when mixed make green. Likewise white light passing through blue and yellow glasses effects a green light. All the colors are present in the white light, but on its passing through the blue glass, the orange and much of the red and yellow rays are absorbed. Then in its passing through the yellow glass, the violet and the blue rays are absorbed, leaving only the green to pass on. However, two separate beams of white light that pass separately through a certain red glass and a certain blue glass, when later they are combined, are still white because, between the two glasses, all the rays have been absorbed and all have been transmitted.

One of the simplest effects man can produce with light is to allow a beam of sunlight to pass through a crystal prism. The emerging light if it is caught on a white surface is arranged in the order of wave length, and all the colors that we can see, from violet to red, are displayed in their greatest purity. Red, orange, yellow, green, blue, and violet do not appear in sunlight in equal parts and their proportions vary under various conditions. The report of one analysis states that sunlight is composed of three parts of yellow, five parts of red, and eight parts of blue. Another gives red 26.8 per cent, green 27.2 per cent, and blue 46 per cent. It seems to be generally agreed that nearly half the light is blue. Thus any light that approximates sunlight would have nearly this proportion of blue in it. Such light can be produced artificially in various ways.

The light from the ordinary carbon incandescent lamp has very

little blue in it, but about 50 per cent of red and 40 per cent of yellow. This accounts for the more yellow appearance of everything under such illumination.

Certain glasslike substances have the quality of dichromatism. When viewed by transmitted light, they appear one color in thin layers and another in thick layers. Thus a wedge of cobalt glass appears blue at the thin edge and through yellow to red at the thick edge. Such effects depend on the absorption coefficient of the substance.

Color sensations can be effected with rotating disks without color that have areas of black and white only. The sensation aroused depends on the relative positions of the black and white areas, the speed at which the disks are rotated, and the order in which one area follows another. Under certain conditions, blue lingers after white and red appears after black.

In normal light, red appears brighter than blue; but in a poor light, blue appears brighter than red. In the dark, a red light is recognized at a distance as red sooner than a green or a blue light can be recognized as green or blue; yet the green or the blue light is recognized simply as a light earlier than the red can be recognized as a light.

Texture or surface structure also has much to do with the appearance of color. A single hue will change in value and vividness as it is associated with different materials. Thus one blue changes part of its character in association with wool, paper, silk, linoleum, cotton, pottery, oil paint, water color, glass, velvet, feathers, fur, metal, etc. The change is due to the way that the material acts on light by means of reflection, absorption, transmission, refraction, etc. The manipulation of colored threads in fabrics affects the color sensation. The alternation of blue and yellow threads can produce a green sensation. A weave that is made of red, orange, and violet threads in regular order will have the same hue, value, and intensity of color as one made of alternate reddish-orange and reddish-violet threads, although the former will have a depth and richness that are lacking in the latter, and the latter will have a delicacy that is lacking in the former.

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14

EFFECTS OF COLOR ON LIFE

That color has definite effects on the minds and bodies of man and some animals and influences the growth of some plant life is an established fact. Man is still groping for the explanations of some of these effects, but in the meantime he is using the power of color as he finds it to accomplish certain ends.

The influence that color can exert on the mind of a man depends on the sensitiveness of the individual. An individual's sensitiveness to color is determined by his alertness, the state of his nerves, his general health, the coordination of his parts, his experience, his education, and by other factors. The impressions received are closely dependent upon associations and the past experiences of the observer. The effects of color on the human organism are as yet only vaguely understood. It is known that under certain conditions, visual impressions (including color) affect the blood pressure and muscular, mental, and nervous activity and mood.

The effect of any color is influenced by its quality, intensity, and predominance, and by the duration of one's exposure to it. It is influenced, besides, by the age, sex, and race of the observer. Color may appeal to the intellect or to the emotions, depending upon the development of the individual. Many tests have been conducted and many observations made by scientists and others to find out what influence color has on people. It has been noted that warm colors are more stimulating than cool colors. Muscular activity was measured under various lights and showed the following effects. Under ordinary light muscular activity registered 23 units, under blue light 24 units, under green 28, under yellow 30, under orange 35, and under red 42 units. Tests indicated that students made greater progress in arithmetic while working under a brilliant red light than they made when under ordinary illumination. A green light is pleasant and restful, but it is not agreeable to look at a face that is illuminated by a green light. White light

containing ultraviolet rays is irritating and can cause headaches. Reflection of white light from snow or a similar surface may cause blindness. Adequate ordinary electric light is most satisfactory for general illumination. An overwarm light is tiring. Too blue a light induces drowsiness. The warm colors are generally stimulating or exciting and the cool colors are generally restful or quieting, but any or all of them may be pleasant or disagreeable. Violet and other adjacent colors may have a depressing or a narcotic effect.

Colors may be pleasing, sickening, stimulating, neutral, subduing, depressing, cheerful, agreeable, or unpleasant. Red, orange, and yellow are stimulating. Scarlet-orange is most exciting or stimulating. A yellow-red may make one feel warm and a deep red may calm one's nerves. Orange may bring comfort if one's spirits are low and if warmth or stimulation are needed, but it may be irritating when it is introduced under wrong circumstances. Yellow usually creates a feeling of warmth and cheerfulness, but a greenish yellow may be sickening. Green may have a peaceful influence, because it is neither cheerful nor sad. Blue, violet, and purple can be depressing; violet is likely to induce a gloomy feeling, while blue is cooling and sobering. It has been proved that color influences sexual activity. The color sensation is received through the eye and the pituitary gland is stimulated. This gland is known to throw into the blood stream certain powerful hormones that influence human behavior. A red light can cause the enlargement of the gonad glands in birds and increase their sexual activity, while a violet light will cause a reduction of these glands.

Color can affect personality and mental outlook as definitely as can a sleepless night, a cold in the head, or a good square meal. An intellectual response comes from an understanding of the forces at work and may range from great pleasure to thorough disgust. With or without understanding, color usually effects an emotional response.

Magenta light has a relaxing, stabilizing effect; violet produces melancholy; yellow stimulates the nervous system. A blue room tends to calm the nerves and restore vitality, while a red room would stimulate the brain and the pulse. Plain interiors of yellow would tend to induce air nausea, and pale-green interiors would tend to eliminate it.

Color helps to make things easy to see; it helps to convey moods; it emphasizes situations and increases audience interest. A deep red-orange is said to have the most exciting influence, a yellow-green the most tranquilizing, and violet the most subduing influence. Bright dots on a dark field create a feeling of happiness. Two bright dots on a dark background cannot be ignored; they demand and get attention. Red can overcome melancholia and blue is effective in treating neurasthenia. Gaudy designs may be useful in repairing shattered nerves. Red-orange can give an impression of warmth and light blue, one of coldness, though no change of actual temperature has taken place. Black clothing makes the body warmer by absorbing heat from the light, and black walls or draperies make a room cooler by the same process. White clothes keep the body cooler by reflecting light and heat, and white walls make a room warmer by the same process. One might be able to play quite comfortably in snow on a sunny slope without clothes, and yet feel cold when fully clothed on the same spot without snow. The snow reflects the sunlight and spreads its heat around, whereas the dark earth absorbs both the light and the heat.

The recorded experiences of some doctors indicate that color has been useful in treating certain types of mental and physical disorders.

Faber Birren, in his book "Selling with Color," mentions an effect that colored lights had on blindfolded subjects. In this instance the subjects stood before the light with arms extended straight out in front. Under the influence of red light, the subjects' arms spread apart; under the influence of green light, the arms tended to come together. This is an instance where color has worked independently of vision.

In his book "Practical Color Management," Frederick M. Crewdson reports on the color cure of Dr. H. Riley Spitler of Ohio. Dr. Spitler effected cures by correcting the physiological symptoms by either stimulating or relaxing the eye nerves. He found that blue or violet lights stopped headaches; red light increased the blood pressure and stopped some types of dizziness; yellow, green, or blue light relieved certain digestive ills; and that yellow light and yellow decorations were beneficial in certain cases of mental disorders.

Dr. Edward Podolsky, in his book "The Doctor Prescribes Color," gives a detailed description of the method of treatment with color. His conclusions of the effects of different colors may be briefly summarized as follows:

Green. The color green affects the nervous system. It is a sedative, a hypnotic, and an anodyne; is useful in nervous irritability, sleeplessness, and exhaustion; lowers the blood pressure by relieving tension; causes a sensation of warmth by dilating the capillaries; relieves neuralgia and headaches associated with high blood pressure. Green is emotionally soothing and no reaction follows its use.

Blue. This is a color that raises the blood pressure by contracting the arteries. It acts on the blood and the effects are tonic. It is antiseptic and lessens suppuration, is effective in some rheumatic conditions or wherever inflammation is present, and is useful in the treatment of carcinoma. Overexposure results in tiredness or depression. For an emotional subject, blue is more soothing than green.

Orange. Orange is an emotional stimulant, which slightly increases the pulse rate. It has no effect on blood pressure, but promotes a sense of well-being and cheerfulness. Overstimulation leads to fatigue.

Yellow. This color is a mental stimulant, useful in cases of mental deficiency. Physically it is beneficial in long-continued doses for tubercular cases, since yellow counteracts the vibrational rate of the disease. Dr. Podolsky states that the effectiveness of some preparations applied to the skin is due more to color vibrations than to any other quality.

Red. A mental stimulant, red is warm and irritating. It aggravates any inflammatory condition, and it increases the activity of the male sex glands. It is effective in adjusting cases of melancholia. Dr. Podolsky reports the case of the employees in the Lumière photographic factory in France. The red light under which they worked had a bad effect on their temper. When the lights were changed to a particular green, the results were excellent.

Violet. Violet acts on the heart, lungs, and blood vessels; and it increases the resistance of tissues. An amethyst light has

the stimulating effect of red and the tonic effect of blue. Violet increases the activity of the female sex glands.

The following is quoted from a report made by Dr. Harry R. Lipton, Psychiatrist, and Dr. George Hess, Chief Medical Officer, of the U.S. Penitentiary at Atlanta, Ga., transmitted to the writer through the courtesy of Joseph W. Sanford, Warden.

> The value of color in the treatment of nervous disorders has been recognized for a long time. Green, blue, and violet are considered to be tranquilizing colors; red, orange, and yellow, stimulating colors. Green tends to produce a feeling of warmth, has a psychological tendency toward lessening pain, and physiologically has a tendency toward lowering the blood pressure. Blue produces a feeling of coolness and is believed by some to have a tendency toward raising the blood pressure.

Color can have good effects if it is applied with knowledge, but it will possibly have bad effects if it is misapplied. Effective treatment of any disorder by means of color is a complex science, involving a considerable knowledge of the patient's physical and mental condition and of the power of color. Therefore it would be unwise to experiment with it until after you have read all the references on it given in the latter part of this book and then only under the guidance of a licensed doctor of medicine.

Little is known about the effect of color on other forms of life than human beings. It is said that red increases the fecundity of flies and that they are repulsed by blue and would thus shun a room painted in that color or illuminated by a blue light. Mosquitoes, on the other hand, are said to be attracted by blue. Some animals are affected by color much as human beings are. As has been mentioned earlier, red light increases the sexual activity of birds by enlarging the gonad glands, while violet light has the reverse effect.

Light of different wave lengths, including visible light, has varying effects on various forms of plant life. The following is quoted from a report by Earl S. Johnston, Assistant Director, Division of Radiation and Organisms, Smithsonian Institution. The report was published by the Smithsonian Institution under the title "Plant Growth in Relation to Wave-length Balance," Jan. 12, 1938.

There can be little doubt that wave-length distribution exerts an enormous influence on the growth of plants. Numerous experiments show that stem elongation is greatly retarded under blue light, whereas an acceleration takes place in the red and near infrared regions. Chlorophyll production takes place better toward the red than toward the blue end of the visible spectrum. Phototropic sensitivity is greatest in the blue and zero in the red. For equal amounts of energy falling on the leaf, two maximal regions of CO_2 absorption have been found—one in the red, the other in the blue. It thus appears that a wave-length region best suited to a given plant process may be entirely without effect upon another. . . .

Although there is experimental evidence to show that different processes go on better in some wave-length regions of the spectrum than in others, yet the best growth, when all the processes are considered simultaneously, apparently takes place in the natural light of the sun . . . So far as is known, there is no available light source which is like that of the sun in its wave-length distribution.

The general process of growth seems to be stimulated by orange-red light and slowed by green-blue light. In the practical application of these effects, in regions and seasons where there is a deficiency of certain colors in the sunlight, this lack can be rectified by artificial means to effect uniform growth. Florists and berry growers are able to put products on the market ahead of season by such means.

The short wave lengths of light generally promote the germination of some seeds and those of long wave lengths inhibit the germination. Red light, which closely approaches infrared, inhibits germination. An excess of ultraviolet light is harmful to plant life and can kill it. Infrared light inhibits the formation of chlorophyll, causes the leaves to turn yellow, and can kill the plant.

From this is may be deduced that the natural growth of plant life depends on light that is visible to us, that each color contributes to some specific process, and that a preponderance of invisible light is destructive.

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15

PREFERENCES

In some instances, preference may be due to aesthetic instinct (an inclination or feeling that may not be understood by the possessor). In other instances, it may be the result of instinct plus acquired knowledge. One prefers a color because it gives him more pleasure or satisfaction than another color. Such satisfaction is largely dependent upon an association of ideas. Unless the spectator is able to correlate what he perceives with some facts or fancies of his own existence, the object of his attention either leaves him cold or is repulsive to him. Conscious judgment of a color is based on the following attitudes: (1) concern with hue, value, and chroma; (2) concern with warmth, life, softness, or loudness; (3) concern with expression of mood—joyful, sorrowful, hopeful, despondent, etc.; (4) concern with fitness, appropriateness, according to association of ideas and experience.

The preference for any color at any time is influenced by association. Thus although a green dress may be very attractive and may be preferred by a person, that same person would be repulsed and horrified if the face of a loved one turned green. The man who chooses red as his favorite color would not think of wearing a red hat. He admires red cheeks but not red hands. In general, everyone likes pure colors and prefers them to broken (mixed) colors when they are not associated with anything. Primitive peoples prefer pure, brilliant, contrasting colors, while civilized people more frequently prefer, in daily use, tints and shades, gradations and broken colors.

Many examinations, tests, and surveys have been conducted within recent years in an attempt to learn what colors are preferred by the majority of persons. The findings have little practical value unless the color in each instance is associated with some definite article or some specific situation.

To ask 1,000 persons whether they prefer red, blue, or yellow would be about as useful as asking them whether they prefer men,

women, or children. The individual would prefer a different color in different connections, just as he might prefer a man teacher, a woman nurse, or a child companion.

A most useful and practical survey of color preference is presented by Birren in his book "Selling With Color." Here indications of color preference are shown for specific commodities, from sales analysis, and we learn that bright-green asphalt roofing is preferred by the majority, that dusty-rose blankets are preferred, and that blue mattresses and black automobiles are preferred among hundreds of others. From a study of "Selling with Color" and "Functional Color," by Birren, the following conclusions have been reached about isolated color preferences.

Infants are most attracted by brightness and richness of hue and prefer red, yellow, green, and blue—in that order. Small children prefer red, blue, green, violet, orange, and yellow, in this order. Mature persons of both sexes, sane and insane, generally prefer blue, red, green, violet, orange, and yellow, in this order. Various surveys indicated that women preferred red first, while men preferred blue first. The preference for tints and shades in both sexes appears to be for tints: blue, violet, red, green, yellow, orange; for shades: violet, blue, red, green, orange, yellow.

Ann Van Nice Gale, in her book "Children's Preferences for Colors, Color Combinations and Color Arrangements," gives the results of numerous examinations and experiments. These investigations seem to indicate that children give preference to orange, red-violet, blue, blue-green, violet, and yellow, in this order when alone, in full chroma, and unassociated with anything. They prefer near-complementary combinations to real complements, except the blue and orange pair. They prefer warm contrasting color combinations to others. Their preference for three-color combinations appears to be, first, orange, green, and violet; second, red, yellow, blue.

J. P. Guilford found that grayed colors are generally preferred; lighter tones of blues and violets are pleasant; green is pleasant with other richer hues; very pale yellows, then dark and light grayish yellows, are chosen; cool colors at high levels and warm colors at low levels are preferred.

Blonds, and those who are native to the temperate zones of the

world, seem generally to prefer blues and greens. Brunets, and those who are native to the tropical zones of the world, seem generally to prefer reds and other warm colors.

Sargent, in "The Enjoyment and Use of Colors," lists preferences in the following order:

Boys: Blue, red, green, violet, orange, yellow.
Girls: Blue, violet, green, red, yellow, orange.
Men: Blue, green, red, violet, orange, yellow.
Women: Blue, green, red, violet, yellow, orange.

Dr. S. E. Katz of New York lists preferences of insane patients in this order: blue, green, red, violet, yellow, orange.

Dr. Edward Podolsky, in "The Doctor Prescribes Colors," points out that everyone prefers to have foods appear in their natural colors and that the relation between the color of a beverage and its container is important. Thus dark beverages should be served in dark glasses, light beverages in light-colored glasses. Milk is best in a plain glass, but a chocolate milk shake would be pleasant in a dark-brown glass, and a strawberry shake in a red glass. There is a preference for meals that are colorful and for color in the dishes on which they are served; however, there need be no relation between the color of the food and the plate on which it is served.

Manufacturers and others who are concerned with providing commodities to the public, in order to operate most profitably, are making use of charts or graphs on which the likes and dislikes of persons in certain communities for certain articles in certain colors are indicated.

There is a relation between color preference and personality. Martin Lang, in his book "Character Analysis through Color," states that much about the character and background of an individual is revealed in his spontaneous choice of pure, unassociated color. This author has evolved the science of "colorology," a new and modern way of revealing the hidden secrets of personality. Briefly, the conclusions are that a choice of the following colors denotes the individual's nature, as stated here.

Red: Vigorous, impulsive, active, sympathetic.
Orange: Convivial, amiable, vacillatory, gregarious.

Yellow: Intellectual, idealistic, philosophical.
Green: Understanding, tolerant, agreeable, trustworthy.
Blue-Green: Discriminative, sensitive, artistic.
Blue: Conservative, sensitive, serious, conscientious, cautious.
Purple: Unusual, mysterious, artistic, self-satisfied, analytical, wise.
Brown: Substantial, dependable, steady, conservative, plodding.

A supplementary choice of the following neutrals would add the indicated attributes to the character of the chooser.

White: Lovely, decent.
Gray: Calm, sensible, conservative.
Black: Conceited, sophisticated.

Lang suggests that it might be wise for a person to marry someone who prefers either the same color as he does or its complement.

In support of the preference of infants for color, the following statement has been received from Harry A. Mohler, President of the Infants Specialty Company of New York, Los Angeles, San Francisco, and Seattle.

There is a gradual trend toward using brighter colors such as reds and blues on purely infants' toys, as against the normal pinks and blues used previously. The purchase of infants' toys in every case is made by adults and they have always felt that pinks and blues (tints) were the colors for babies. Numerous tests have been made by manufacturers and the results show that in every case the infant actually selected bright colors and not the pink or blue (tint).

It was stated that color preference is contingent upon many things, not the least of which is an association of ideas. Norman C. Meier, Department of Psychology, University of Iowa, Iowa City, notes the following:

Greenish yellow is, in American culture, a less preferred color to other colors, such as red or blue-green. The basis for this evaluation lies in the fact that greenish yellow has consistently been associated with filth, disease (jaundice, yellow-fever, quarantine), and cowardice. Language responses have tended to reinforce the emotional conditioning, as have also mimetic responses involving olfactory and other experience. But

with other peoples and cultures, yellow, only slightly removed, has been a sacred hue. Similarly, white runs the gamut of symbolizing purity and saintliness to the white flag of abject despair and surrender.[1]

Acknowledgment is given to the following sources of information. See also Part Seven.

BIRREN, FABER: "Functional Color," The Crimson Press, New York, 1937.

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SARGENT, WALTER: "The Enjoyment and Use of Color," Charles Scribner's Sons, New York, 1923.

[1] Inter-Society Color Council Symposium, "Color in Art Education," February, 1942, printed in the *Journal of the Optical Society of America*, Vol. 32, No. 12, pp. 698–726, December, 1942.

16

COLOR NAMES

It has been stated that the human eye can distinguish differences among two million or more colors and shades. So far, about 7,000 colors and shades have been tabulated, but standard English dictionaries list only about 3,400 words for colors and shades. Through the ages, as man has become more and more concerned about color, he has found it desirable and necessary to have words and symbols to convey thoughts and information about colors through speech and writing. Such words have been developed to a large extent from association with objects that have such colors, as orange, lemon, peach, cherry, grass green, sea green, emerald green, turquoise, ruby, etc. Even now, any commonly used words or combination of words are not completely adequate to describe an exact color sensation. The word "red" alone may cover many hundreds of thousands of colors containing red in various shades and tints. Unless the word used is associated with some well-known object, we fail to recognize exactly what color is designated by it. There is no general standardization of color names.

In botany, color is anything but green. In antique languages, words to represent the colors red and yellow were developed before there were any words for green and blue. Red and yellow pigments were more common in antiquity than pigments of green and blue, although the Egyptians used green and blue. Some tribes have a single name for whatever appears red, orange, or purple; another name to apply to objects that appear black, blue, or violet; and another for things that are white, yellow, and green. Perhaps because red is not common in nature, a special word was required for it by early man; at any rate, nearly every language has a word for red. Almost every language has a word for yellow, while comparatively few have a word for green and still fewer a word for blue. In some American Indian languages there were no names for colors, the idea being conveyed solely by comparison or association with a well-known object.

Our language is richer in names for color sensations on the red

end of the spectrum than for those on the violet end. Scientists can accurately describe any spectral color sensation by giving its wave length or rate of vibration. Any accurate description of a color sensation would involve, among other qualities and conditions, its hue, value, and chroma. Scales have been devised to convey these ideas, but they are useful only in the realm of science and industry. Since we can experience several thousands of color sensations and it is not practical to have a name for each, a vivid imagination and considerable mastery of words are needed for conveying such ideas by writing.

In an effort to standardize color names, A. G. Werner in 1814 wrote a book in which he named and described 110 colors. In 1892, William Hallock wrote about 388 colors. Books on the subject have been written also by Chevreul, Munsell, Ostwald, Bezold, Rood, Radde, Klincksieck, Valette, Luckiesh, Birren, and others. In 1905, a French work, "Répertoire de Couleurs," described 1,356 colors. In 1912, Robert Ridgway wrote about 1,113 color names. In 1915, the Textile Color Card Association was organized to standardize color names for various industries. In 1930, A. Maerz and M. Rea Paul published "A Dictionary of Color," which presented 7,000 colors.

Before Christ, a Greek named Theophrastus wrote a "History of Stones," in which he discussed the subject of color. In the first century after Christ, Vitruvius Pollio and Pliny wrote about color. In the eleventh, twelfth, and thirteenth centuries, three other books were written in Latin about color by Theophilus, Adelard of Bath, and Eraclius. In the fifteenth century, two books in Latin and one in Italian; about 1500, two books in Italian and one in English; and about the year 1600, eight more books in English were written pertaining to color. Following these, 10 books on the subject were produced in the eighteenth century, 73 in the nineteenth, and about 55 during the first quarter of the twentieth century.

The English names for a few colors have been derived as follows (abbreviations—ME Middle English, AS Anglo-Saxon, OF Old French, OHG Old High German, ON Old Norse, SKR Sanskrit, L Latin, D Dutch, G German, IT Italian, F French, GR Greek, AR Arabic, PR Provençal, DAN Danish, SW Swedish, LITH Lithuanian, GO Gothic, WE Welsh, BR Breton, GA Gaelic, PER Persian, SP Spanish):

Red: The color of blood, rubies, roses, etc. ME red, reed, read; AS rēad, rēod, rōd, rād; D rood; G rot; OHG rōt; DAN and SW röd; ON rauther, rjothr; GO rauths; WE rhudd; BR ruz; GA ruadh; L ruber, rufus; GR erythros; SKR rudhira, rohita; LITH raudas.

Orange: The color of some ripe oranges (reddish yellow). OF orange; F orange; PR auranja (aura for gold); AR naranj; PER nārang; SKR nāranga; SP naranja.

Yellow: The color of sulphur, ripe lemons, butter, sunflower. ME yelow, yelwe, ʒelow, ʒalowe, ʒolou; AS geolu; D geel; OS and OHG gelo; G gelb; ON gulr; L helvus; GR chlōe, chlōras; LITH ʒalias.

Green: Color of growing grass and emeralds. ME grene; AS grēne; D groen; OS grōni; OHG gruoni; G grün; DAN and SW grön.

Blue: The color of clear sky (zenith), deep sea, and sapphire. ME bleu, bla, blew; OF bleu; OHG blāo; G blau; ON blār; AS blāw; D blauw.

Violet: The color of the flower, violet (reddish blue). ME violett, vyalette; OF violete; FR violette; L viola.

Purple: A bluish red. ME purpel, purpre, purpur; AS purpure; OF purpre; F poupre; L purpura; G porphyra.

Beige (bāzh): A light reddish yellow, like unbleached wool. IT bambagia; L bambox.

Brown: The color of some earth, unbleached linen or paper, dark skin, oak leaves in late fall. ME broun, brūn; AS brūn; D bruin; OHG brun; G braun; ON brūnn; LITH beras; SKR babhru.

Black: The color of soot or of crow feathers. ME blak; AS blaec; ON blakker; SW bläck; OHG blah; D blaken.

White: The color of pure snow, milk, lily, etc. ME whit; AS hwīt; D wit; G weiss; OHG wīz, hwiz; ON hvītr; SW hvit; DAN hvid; GO hweits.

A comparison of some major color names from some European languages and Latin follows.

English	German	French	Italian	Spanish	Portuguese	Latin
Red	rot	rouge	rosso	rojo	vermelho	rufus
Orange...	orange	orange	arancia	naranja	laranja	aurantium
Yellow...	gelb	jaune	giallo	amarillo	amarelo	flavus
Green....	grün	vert	verde	verde	verde	viridis
Blue......	blau	bleu	azzurro	azul	azul	caerulus
Violet....	veilchen	violette	violetta	violeta	violeta	viola
Black.....	schwarz	noir	nero	negro	prêto	nigrum
White....	weiss	blanc	bianco	blanco	branco	albus
Gray.....	grau	gris	bigio	gris	pardo	cānus

No color names convey an exact idea of the color to all persons. While many color names have developed from association with familiar objects, such as orange with the fruit of that name, the word "orange" covers hundreds of different color sensations. Some manufacturers, unable to find any suitable color names for their products have created such names as "Midsummer Night's Dream," "elephant's breath," "Maiden's Prayer," etc., which seem to serve their purpose as well as or better than any commonly used color names.

From the *Inter-Society Color Council News Letter* [1] comes the following note:

1946 Spring Woolen Colors. The Textile Color Card Association of the United States, Inc., according to its managing director, Mrs. Margaret Hayden Rorke, has recently issued its advance woolen collection for spring, 1946, commemorating the triumphant theme of Victory and Peace by means of colors of freedom. These brilliant colors include hope turquoise, Pacific lime, orange glory, peace blue, brave red, triumph gold, gallant coral, victorious blue, valor rose, and heroic green. They are smart for sports and play clothes and contrast with more neutral colors for town wear.

In a lighter and softer register are the summery frappé pastels, which include lemon ice, glacé violet, frosted mint, ice aqua, crushed peach, pistachio cream, ice-cream pink, rum frappé, apricot mousse, and candy blue. This pastel range has interest for resort and children's wear but may also be combined with darker colors like navy and black. Wide fashion acceptance for the green range is anticipated and is represented by plaza green, coolgreen, lime jade, sun olive, aquadew, and seaway green, the last two being bluer greens. Among the basic colors of a neutral type are champagne blonde, cream caramel, pearl oyster, and flotilla gray; while more exciting colors are mandarin rose, celestial pink, exotic turquoise and China peacock, reflecting Chinese inspirations; and California blue, midship blue, terra-cotta red, rose melon, Chili spice, cloud coral, violet dawn, and wild clover.

Color Names and Descriptions

Reds and Pinks

Alizarin: An orange-red.
Amaranth: A bluish red like magenta.

[1] *Inter-Society Color Council News Letter*, No. 61, September, 1945.

American Beauty: A dark, purplish red.
Araby pink: A slightly bluish pink.
Ashes of roses: A grayed red of medium value.
Azalea: A tint of orange-red found in the pinkish flower of the same name.
Baby pink: A delicate, pale tint of pink.
Beet: A deep purplish-red color found in the vegetable of that name.
Beetroot: Dark red in shade.
Begonia: A shade of slightly yellow red found in the flower petals of this plant.
Blood red: A rich, slightly bluish red.
Blossom: A soft, delicate pink color.
Blotter pink: A medium tint of slightly bluish pink used for blotters.
Blush rose: A very rich rose shade.
Bonbon pink: A pastel pink seen in candy; also called "candy pink."
Bordeaux: A warm, bluish-red color, the shade of the wine of the same name.
Botticelli pink: A magenta tint.
Brick red: A rich, deep orange-red.
Burgundy: The color of red wine; a shade less blue than Bordeaux.
Cardinal red: A brilliant, rich red, as of the cardinal bird's plumage.
Carmine: A rich red with a cast of purple.
Carnation: The dark-red color of the flower of the same name.
Carnelian: A light shade of red-brown found in the semiprecious stone of the same name.
Castilian: The most intense red possible.
Cerise (French for cherry): A light bluish red.
Cherry: A bluish red, as of the fruit.
Chianti: A deep cerise, as of the Italian wine.
Cincinnati red: A brilliant, rich orange-red.
Cinnabar: A medium shade of orange-red, as of the stone of that name and of red Chinese lacquer.
Claret: A shade of bluish red found in wine of the same name.
Coral: A tint of yellow-red seen in the natural coral.
Coxcomb: A moderate shade of bluish red.
Cranberry: Dark, purplish red.
Crevette: Pink like the color of the shellfish, shrimp.
Crimson: Any of several colors ranging in hue from true red to a bluish red.
Crimson lake: A slightly blued red.
Dahlia: A bluish-red color, as of the flower.

Dark cardinal: A rich, deep violet-red hue.
Derby red: A rich, deep orange-red.
Dubonnet: A dark blue-red, as of the French *apéritif.*
Egyptian red: A brilliant, rich red.
Fiesta rose: A pink stronger than Araby pink.
Fisherman red: As of the red-orange sails of Belgian and Venetian fishing boats.
Flame: A scarlet color resembling a body of burning gas and vapor.
Flamingo: A yellowish-red tint, as of the bird.
Flesh: A soft, pale pink, with a slight yellow cast.
Fondant pink: A pastel tint of pale red, as in candy.
Fraise (French for strawberry): Bright red, like the fruit.
Framboise (French for raspberry): Bright red with a bluish cast, like the fruit.
Garnet: A deep red, as of the mineral.
Geranium: A yellowish red.
Goya: A very rich, deep orange-red.
Granada: A rich, deep, dark red.
Grecian rose: A dull, crimson-brown rose shade.
Hacienda red: Red with the slightest blue cast.
Harvard crimson: A rich, deep cherry color with a violet-crimson cast.
Heliotrope: A blue-red.
Homard: The pinkish red color of the lobster.
Incarnat: Carnation red.
Indian red: Dark brownish red.
Indo red: Intense red with a yellow tint; lighter than Castilian.
Jacqueminot: Jack rose; a bright-red rose color.
La France: A deep, pink-rose shade.
Lacquer: A shade of orange-red found in Chinese lacquer.
Laurel pink: A medium grayed-pink tint.
Lobster: A bright orange-red.
Magenta: A peculiar shade of purplish red.
Maple-leaf red: A rich, deep orange-red.
Maréchal Niel: A pale yellow-rose shade.
Maroon: A rich, dark red.
Nude: A pastel tint similar to skin color.
Old rose: A soft, dull, rose-pink shade.
Oxheart: Dark red.
Paprika: A light orange-red color.
Petal pink: A delicate pink found in the petals of apple blossoms.
Pigeon blood: A deep red.

Pimento red: A bright orange-red.
Pompeian red: A deep orange-red shade.
Poppy: A brilliant orange-red.
Raspberry: A dark, purplish red.
Red oxide: A deep orange-red.
Rose: A red of middle value, grayed.
Rose Aurore: Similar to the pink of the sunrise.
Rosebud: A medium, delicate, light pink.
Rose crevette: A shrimp pink.
Roseglow: A warm rose-tan shade.
Ruby: A rich, medium red with a blue cast.
Sail red: Lighter and brighter than fisherman red.
Scarlet: A brilliant orange-red of great intensity.
Shell pink: A tint of red found in certain seashells.
Shrimp: A tint of yellow-red found in the delicate color of cooked shrimp.
Strawberry: A shade of slightly bluish red.
Sweet pea: A pink.
Tabasco red: Bright orange-red.
Tangerine red: Brilliant orange-red.
Tea rose: A soft, delicate yellow-pink.
Tile: An orange-red.
Tomato: The brilliant orange-red of the tomato.
Turkey red: A yellowish red.
Venetian red: Orange-red.
Vermilion: A bright-red color, from crimson to almost orange.
Victoria red: A deep orange-red.

Yellows

Alp green: A shade of green-yellow.
Apricot: A tint of pinkish yellow.
Asphodel (French for daffodil): A dark yellow.
Aureate: A golden yellow.
Azurite: The yellow color of the metal, a copper ore.
Banana: A shade of yellow similar to the color of the skin of this fruit.
Butter: The bright orange-yellow of salted butter.
Buttercup yellow: A light, clear tone of yellow found in the petals of the buttercup.
Cadmium lemon: A brilliant yellow.
Canary: The yellowish color of the canary's plumage.
Cantaloupe: A pale, pinkish yellow color, named after the melon.

Champagne: A light, yellowish tint.

Chartreuse: A green-yellow tint.

Chrome: A reddish-yellow tint.

Chrysanthemum: A very strong, brilliant yellow, the color of the most common flower of the chrysanthemum family.

Citron: Brownish yellow in color.

Corn: A clear, light yellow.

Cream or *Crème:* The light tint of yellow to be seen in cream.

Crocus: The warm shade of slightly orange yellow found in the spring flower, crocus.

Daffodil: A yellow like that found in the early spring flower, daffodil.

Dandelion: An intense shade of yellow, such as that found in the petals of the flower, dandelion.

Dragon: A brilliant green-yellow.

Flambe: The color of the yellow iris.

Flax: A light color like that of straw.

Gold: A brownish yellow, as in jewelry and coins.

Goldenrod: A shade of orange-yellow found in the flower, goldenrod.

Henna: A brown reddish yellow.

Honey: The light amber-yellow tint found in honey.

Indian: A yellowish red-yellow.

Jasmine: A pastel tint of yellow.

Leghorn: A yellow wheat or straw color.

Lemon: A medium tint of yellow, characteristic of the ripe fruit of the same name.

Maize: An orange-yellow.

Marigold: A bright shade of orange-yellow.

Mustard: A reddish yellow, as of powdered mustard seed.

Ocher: A brownish yellow.

Old gold: A rich, lustrous, satiny yellow.

Primrose: A delicate tint of yellow.

Saffron: A yellow.

Sienna: An orange-yellow.

Sulphur: A pale greenish yellow.

Sunflower: A deep orange-yellow.

Tarragon: A soft, grayed green-yellow.

Yellow ocher: A dull yellow.

Zinc yellow: A brilliant greenish yellow.

Blues

Aquamarine: A green-blue of light or medium value.

Azure: The blue of a cloudless sky on a summer day.

Baby blue: A tint of blue.
Bleuet (French for cornflower): The blue that is typical of the cornflower.
Bleu hirondelle: A gray-blue.
Bleu paon: A shade of peacock blue.
Bluebell: The color of the bluebell, Scotland's national flower.
Bluebird: The characteristic color of this bird's feathers; a deep, bright blue.
Blue turquoise: From the semiprecious stone, turquoise, which is nearer blue than green.
Bonny blue: A medium blue, known also as Scotch blue.
Botticelli blue: A pale, hazy color with soft gray tints.
Cerulean: The color of blue sky.
China blue: A shade of lavender blue.
Ching: A deep, brilliant, slightly greenish blue.
Chow: A brilliant blue, slightly darker than primary blue.
Clematis: A bright-blue color, as of the flower, clematis.
Cleopatra: A brilliant Oriental blue, slightly tinted with green.
Cobalt blue: A bright blue with no green cast, similar to ultramarine.
Copenhagen blue: A brilliant purplish blue.
Cornflower: A slightly reddish-blue tint.
Delft blue: A reddish blue.
della Robbia blue: A brilliant pottery blue made famous by a Florentine sculptor, della Robbia.
Delphinium: A violet-blue.
Devonshire blue: A soft delphinium blue.
Electric blue: A cool, greenish blue, resembling an electric spark.
Empire blue: A greenish gray-blue.
Ensign: The pure, dark blue used for naval uniforms.
Flag: A shade of blue similar to the bright and dark blue of the flower iris.
Flax blue: A shade of slightly purple blue.
Flemish blue: A rich, deep grayish blue.
French blue: A medium greenish blue.
Gentian: A reddish blue.
Grotto blue: A bright blue.
Heather: A shade of grayed purplish blue.
Homage: A very dark ultramarine blue.
Iris: A reddish blue, as found in the wild iris.
Jockey club: A dark blue.
Lapis: A medium shade of purplish blue.

Lucerne blue: A medium bluish lavender.
Lupine: A tint of purplish blue.
Madonna blue: A medium purplish blue.
Marine: A very dark blue.
Midnight blue: A dark blue, almost black in hue.
Morning-glory: A bright, light blue.
Mulberry: A reddish blue.
National blue: A medium blue like that used in the American flag.
Navy blue: A dark blue.
Old china: A medium grayish blue.
Peacock blue: A bluish green-blue.
Peking: A deep grayish blue.
Periwinkle: A light purple-blue.
Plover-egg blue: A tint of gray-blue.
Porcelain blue: A tint of lavender blue.
Powder blue: A gray green-blue.
Prune: A deep purple-blue.
Purple navy: A dark purplish blue.
Robin's-egg blue: A tint of green-blue found in robins' eggs.
Royal blue: A slightly purple-blue shade.
Sapphire blue: A deep-blue shade with a slightly greenish cast.
Saxe blue: A soft, pale greenish blue.
Schooner blue: A dark blue.
Shipblue: A dark purple-blue.
Sky blue: A blue resembling the color of the sky on a clear summer day.
Turquoise: A bright green-blue.
Ultramarine blue: A rich, deep-blue shade.
Yale blue: A brilliant, medium blue with a green cast.

Purples and Violets

Amethyst: A deep bluish purple.
Bruyère: Heather color; a grayed blue-purple.
Cathay: A blue-purple tint.
Chou rouge (French for red cabbage): A deep reddish purple.
Clover: A pinkish lavender.
Cobalt violet: A brilliant violet.
Cochineal: A deep reddish purple.
Crème de viollette: An intense tint of purple.
Crystal mauve: A tint of blue-violet; the color of the flower bluebell.
Eggplant: A rich, dark purple.
Fuchsia: A purple with a reddish cast.

Imperial red: A rich, deep bluish red-violet.
Japanese iris: An intense blue-purple.
Lavender: A tint of reddish purple.
Lilac: A tint of bluish red or pale lavender.
Lotus blue: A tint of blue-purple.
Mauve: A delicate purple-violet.
Mignon: A pale bluish violet.
Monsignor: A bright reddish-violet shade.
Orchid: A red-violet.
Pansy: A rich, deep reddish purple.
Plum: A purple.
Thistle: A shade of purple.
Tyrian purple: A crimson-purple.
Vistal: A soft, delicate lavender, with a pinkish cast.
Wistaria: A light purple.

Greens

Absinthe: A tint of green or a light yellow-green.
Almond: A gray-green tint found on the under side of almond leaves.
Apple green: A tint of yellow-green found in green apples.
Aquagreen: A soft, pale, yellowish green.
Aquarelle: A light blue-green, greener than aquamarine.
Arcadian green: A light yellowish green.
Billiard: A brilliant shade of yellowish green seen in the felt on billiard-table covers.
Bird's egg: A tint of blue-green, the color of robins' eggs.
Blue spruce: A grayed blue-green; the shade found in the new growth of the tree of that name.
Bottle green: A bright green with a bluish cast.
Brewster green: A dark blue-green, popular for coachmen's livery in the Victorian era.
Brittany: A blue-green, bluer and darker than bird's egg.
Bud green: A light, refreshing yellow-green.
Chrome green: A dark bluish green.
Diana: A lovely, rich, deep greenish shade.
Emerald green: A deep, slightly yellow green (emeraude).
Épinard (French for spinach): The soft dark green of the vegetable spinach.
Evergreen: A yellow-green, as of the evergreen tree.
Forest green: A dark blue-green.
Golf green: A medium-brilliant green.

Grass: A yellowish green.
Ingénue: A yellow-green.
Ivy: The dark green of ivy leaves.
Jade: A shade of yellow-green.
Jasper: A yellowish green.
Jungle green: A dark yellowish green.
Leaf green: A tint of yellow-green often seen in young leaves.
Lettuce: A tint of yellow-green; the color of lettuce leaves.
Lichen: A whitish-green color, like that of the plant lichen, which is composed of white and greenish cellular fungi.
Lime: A yellow-green.
Mint green: A shade of gray-green.
Moss green: A yellowish green.
Nile green: A tint of yellow-green.
Ocean green: A pale yellowish green.
Olive (olive green): A shade of yellowish green.
Paris green: A vivid yellow-green, more intense than grass.
Parrot green (parakeet): A brilliant yellow-green.
Pea: A tint of yellow-green found in fresh peas.
Peridot: A deep yellowish green.
Pine: A soft, dark green.
Pistache: A yellow-green.
Psyche: A medium-pale yellowish green.
Rickey green: A bright yellow-green.
Sage: A deep yellow-green.
Sea green: A shade of clear blue-green, such as is seen in deep water.
Spinach: A dark yellow-green seen in the outer leaves of the vegetable spinach.
Spring green: The fresh yellow-green of new leaves.
Teal: A dull bluish green.
Verdigris green: A brilliant blue-green.

Oranges

Amber: A honey color or reddish orange.
Brilliant orange: The color of the citrus fruit of that name.
Burnt orange: A medium red-orange shade.
Capucine (French for nasturtium): A pale, yellow-orange color.
Carrot: A red-orange, as of the vegetable carrot.
Corabell: A slightly crimson-orange shade of coral.
Coral blush: A soft, pale, reddish-orange tone.
Crab apple: A light reddish orange.

Fiesta: A reddish-orange shade.
Indian orange: A brilliant reddish orange.
Kumquat: A yellowish orange similar to the color of the Chinese citrus fruit of that name.
Leafmold: A deep reddish-orange shade.
Old coral: A reddish orange.
Peach: A red-orange tint.
Rio rust: The deep yellow-orange of rust on iron.
Salmon: The shade of red-orange found in the flesh of the salmon.
Terra cotta: A yellow-orange, as of baked clay.
Topaz: A tint of yellow-orange.

Browns

Acajou: A mahogany or reddish-brown color.
Amadou brown: The rich red-brown color of chocolate.
Argil: A light, reddish-brown clay color.
Auburn: A reddish-brown color familiar as a color of hair, lighter than brunet and darker than titian.
Autumn brown: A rich red-brown shade often seen in the colorings of nature.
Badger: A grayish-brown shade, the same as the coloring of the badger's fur.
Beaver: A neutral, grayed-brown color seen in the coat of the fur-bearing animal of that name.
Beige: A light, neutral tan.
Bisque: A warm, pale tan, similar to the color of the composition used for the making of dolls' heads.
Bistre: A dark, yellowish brown.
Bois de rose (French for rosewood): The rich, reddish-brown color of that wood.
Bronze: A rich, lustrous greenish-brown tone.
Brown: The color of a dead leaf. There are warm browns, with orange or red predominating, and cool browns with blue predominating.
Buff: A light yellow-brown tint.
Burnt sienna: A color named from the yellowish- or reddish-brown clay pigment called "burnt sienna."
Burnt umber: A dark, dusky brown.
Café: The color of coffee.
Café au lait: The color of coffee with milk.
Cannelas: A cinnamon color.
Caramel: A light shade of yellow-brown, as of burnt sugar.

Cedar: A shade of reddish brown.
Chamois: A yellow-beige shade, as of chamois leather.
Chestnut brown: A rich, deep, yellowish brown.
Chocolate: A deep purplish brown, as of chocolate candy.
Cinnamon: A shade of red-brown seen in the ground spice cinnamon.
Citrine: A yellow-brown color, such as light khaki.
Clovedust: A rich, reddish-brown beige.
Cocoa: A brown, red-yellow in hue.
Coffee: A light brown.
Cognac: A light brown or amber, like brandy.
Copper: A rich shade of red-brown.
Cork: A neutral tan.
Cuir (French for leather): A rich, warm yellowish brown.
Deer: A medium grayish brown.
Ecru: A color similar to the beige of unbleached silk and linen.
Eggshell: A delicate beige, similar to the outside of the shell of a hen's egg.
Fallow: A light yellowish brown.
Fawn: A light yellowish brown.
Fox: Generally a yellowish brown, red-yellow in hue.
French beige: A yellowish beige with an undertone of rose.
Ginger: A shade of red-brown.
Golden brown: A deep, yellowish-brown shade.
Grain: A warm tan tint.
Hazel: A soft reddish brown.
Hickory: A deep grayish brown.
Inca brown: The very deep brown of dark leather.
Indian brown: A deep reddish yellow-brown.
Khaki: A yellowish-green dust color.
Leather brown: A warm brown shade characteristic of shoe leather.
Mahogany: A deep shade of reddish brown.
Manila: A pale yellowish tan.
Marron glacé: A pale, warm yellowish brown.
Mocha: The color of coffee with cream.
Modern brown: A rich, deep yellowish brown.
Monkey skin: A rich, warm pinkish tan.
Mummy: A medium yellowish brown.
Nutmeg brown: A dark shade of grayed brown.
Oakwood: A medium, warm yellowish brown.
Olive brown: A rich, yellowish, golden-brown shade.
Pueblo: A golden tan.

Rattan: A warm, light brown.
Rembrandt: A rich yellow-brown.
Russet: A shade of greenish brown.
Rust: The reddish brown of iron rust; clay color.
Sandalwood: A warm beige, a little darker than tan.
Seal: A dark-brown color, as of the inner fur of a seal.
Straw: The light tan of straw.
Terrapin: A golden brown.
Terreau: A blackish brown, the color of the earth.
Tobacco: A warm, deep brown with a slight yellow cast.
Umber: A brown earth color, with sometimes a slightly reddish hue.
Zulu brown: A reddish brown shade.

Grays

Acier (French for steel): A color that reflects the same tones as that metal.
Antique ivory: The color of old ivory, with a slight yellow or orange cast.
Argent: A greenish, light, neutral gray, derived from the French *argent*, meaning silver.
Blue steel: A dark bluish-gray shade.
Cadet blue: A light bluish gray.
Canard (French for duck): The gray color of a duck.
Castor: A dark brownish gray.
Cendre (French for ashes): A pale gray.
Chalk: A dullish white.
Chromium: A gray, as of the metal of that name.
Colombe (French for dove): A pale gray, like that of a dove.
Corbeau (French for raven): A color nearly black in tone, with high lightings of green.
Crane: A medium, yellowish gray color.
Dove gray: A blue-gray tint found in the feathers of a dove.
Dutch blue: A light bluish gray, brighter than cadet.
Eel gray: The dark shade of blue-gray seen in the skin of the live eel.
Elephant: A dark gray.
French gray: A soft gray with a slight purplish cast.
Graphite: A dark steel gray.
Gull: A tint of gray like that found in the plumage of gulls.
Gun metal: A deep bluish-gray shade, generally used in leathers.
Horizon blue: A light bluish gray.
Iron: A tint of black.
Iron gray: A dark brownish gray.
Ivory: A tint lighter than cream, found in elephants' tusks.

Jet: An intense, lustrous black.
Lamp black: A dull tone of black.
Maltese: A blue-gray.
Mist: A light-gray shade.
Mole gray: A shade of brownish gray.
Mouse gray: A tint of gray found in the color of the field mouse.
Nickel: A rather lustrous pale gray.
Nugrey: A blue-purple gray.
Oyster gray: A brownish gray tint found in the shell of the oyster.
Pearl gray: A light bluish gray.
Pelican: A medium-gray shade.
Pigeon: A medium yellowish gray.
Putty: A warm, medium gray.
Raven: A deep greenish black.
Sand: A light, warm, yellowish gray.
Santaupe: A light gray with a pinkish tint.
Silver: A pale, lustrous gray.
Silver gray: A pale blue-gray.
Slate: A dark bluish-gray shade.
Smoke: The shade of blue-gray seen in dense smoke.
Steel gray: The shade of blue-gray reflected in steel.
Taupe (French for mole): A gray the color of moleskin.
Turtle dove: A medium yellowish gray.
Zinc: A medium gray with a dull-yellow cast.

Color Designation

In an effort to develop a useful system of accurately designating colors, many men have labored for many years. An interesting summary[1] of this work, included in "Color-mixing Systems," by Donald R. Dohner of Pratt Institute, Brooklyn, N.Y., and Carl E. Foss, color consultant, New York, is quoted here:

Ostwald, in J. Scott Taylor's translation of "Colour Science,"[2] has developed a brief history of many of the contributions of past workers; he goes back to the Greeks and the Romans; to Goethe, who collected but never completed, material for a history of color; to Newton, who found

[1] From a paper originally published in the *Journal of the Optical Society of America*, Vol. 32, No. 12, pp. 698–726, December, 1942.

[2] Ostwald, Wilhelm, "Colour Science," trans. by J. Scott Taylor, Vol. 1, Windsor and Newton, Ltd., London, 1931.

that sunlight could be broken up into separate colors; to Le Blond, who first used Newton's seven colors (about 1730) for color prints and found later that he could obtain the same result with three; to Gautier, his competitor, who arrived at an identical solution about the same time; to Dufay, who, about 1737, described how dyeing of yarns and fabrics could be done with three colors; to J. Brenner, who published a Color Table in 1680 in Stockholm, giving a list of the coloring matters then known; to R. Waller, who in 1689 made a color chart with washes of color; to Tobias Mayer, who made charts of all combinations obtained to 12 steps on a basis of a red-yellow-blue triangle, with several charts for black and white combinations; to J. H. Lambert, who made a pyramid by pigment mixtures, based on Gamboge, carmine, and Prussian blue; to Philip O. Runge, the painter, who added the idea of decreasing to black, as well as to white, the basis for his sphere; to Chevreul, chemist and dyer of the famous Gobelin Works, who, although he contributed nothing new to mixture problems, created much interest and called attention to problems of simultaneous contrast. Ostwald points out that Lambert, Runge, and Chevreul recognized the three-dimensional nature of color; that Runge clearly grasped that black and white are independent colors (Mayer and Lambert not quite sure), but Chevreul not at all. Up to this time no workers attempted to produce or suggest a measured system.

In 1810 Goethe published his *Farbenlehre*. Schopenhauer, a pupil of Goethe's, laid emphasis on cerebral activity in color experience. Two generations later Hering repeated the physiological part of the work, and Ostwald himself used portions of this theory in his "Doctrine of Semichromes." Helmholtz (1821–1894) added the conception of additive and subtractive mixture, and determined complementaries. Young, in 1807, contributed the theory that there is a red, green, and violet receiving mechanism in the retina, and Helmholtz developed this theory further. Grassman formulated the laws of color mixture. James Clark Maxwell needed measurement, so he used disks, applied Grassman's laws, and found equations that held, and that colors mix on straight lines of junction in a color-mixture triangle. Hering, 1834–1918, turned to psychological analysis and inquired into "experience" of colors, not into the spectrum. Schultze in 1866 suggested that rods and cones might have different functions, the rods to distinguish light-to-dark, the cones to distinguish all color differences, including light-to-dark. But Helmholtz paid no attention to this theory. Later Von Kries and Parinaud advised the same theory, and more recently E. Muller; it is now generally accepted. To this list must be added the names of Brewster, Scottish chemist, author of the red-yellow-blue theory that unfortunately has been so

widely used in the American educational system; of Rood, an early American color scientist, who suggested the use of a double cone, following on the ideas of Lambert and Runge; of Ladd-Franklin who so capably championed her theories of color vision; of Frederick E. Ives, father of modern color printing; of Munsell, who added measurement and standardized charts for demonstration of a color notation; of Troland, whose interests lay in psychophysical problems; of those who developed Technicolor, Kodachrome, and other processes of modern color photography; of Hecht in his physiological studies of vision; and of many a worker in the National Physical Laboratory of Great Britain and in the National Bureau of Standards of this country who did the careful and tedious work that necessarily preceded the adoption, in 1931, of data to represent a standard observer for colorimetry, standard illuminants for colorimetry, standard observing conditions, and a standard coordinate system.

The Ostwald System. Wilhelm Ostwald, born in Riga, Latvia, in 1853, was a chemist and amateur painter. His research in the field of color, begun seriously after he was sixty-one years old, has greatly contributed to our present knowledge and use of it. He developed the "color solid," in which colors were given an orderly arrangement according to chromatic and black and white content. His hue circuit (color wheel) embraced yellow, leaf green, sea green, turquoise, ultramarine blue, purple, red, and orange, each in three divisions and each occupying an equal proportion of the circuit. The color solid was so developed that, by a series of numbers and symbols, each color represented could be designated and would show approximately the proportions of chromatic, white, and black pigment required to produce a daylight match for the surface.

The Inter-Society Color Council—National Bureau of Standards System. This method of designating colors provides for about 300. It supplies a nonnumerical designation, which is systematically arranged. Deane B. Judd, in "Color Systems and Their Inter-relation," describes the method as follows:

The designations for all but nearly achromatic colors consist of a hue name (red, orange, yellow, green, blue, purple, pink, brown, olive), preceded by modifiers (light, medium, dark, vivid, strong, moderate, weak, brilliant, dusky, pale, and deep), indicating the lightness and

saturation of the perceived color. Nearly achromatic colors are designated white, gray, or black with modifiers indicating hue and lightness (such as dark greenish gray). These designations were suggested by the surface-color solid. The boundaries between the groups of colors known by these designations have been adjusted to accord as closely as possible with common usage and have been expressed in terms of the Munsell color system.

The ISCC-NBS method of designating colors has been approved for the description of drugs and chemicals by the voting delegates of the following member bodies of the Inter-Society Color Council:

American Association of Textile Chemists and Colorists.
American Ceramic Society.
American Psychological Association.
American Society for Testing Materials.
Illuminating Engineering Society.
National Formulary, American Pharmaceutical Association.
Optical Society of America.
Technical Association of the Pulp and Paper Industry.
United States Pharmacopoeial Convention.

The Birren System. Faber Birren, color consultant, New York, has developed a system of designation, based on the Ostwald system, which recognizes each color as having seven forms: color (hue), white, black, tint, shade, tone, and gray. In verbal designation he generally follows the method of the ISCC-NBS (Inter-Society Color Council—National Bureau of Standards). His color circuit includes yellow, yellow-leaf, leaf, green-leaf, green, turquoise, blue, violet, red-violet, red, red-orange, orange, and yellow-orange. He has arranged the colors on the circuit so that the brighter and warmer colors occupy a greater proportion of the circle than the darker and cooler ones do, and has moved the point of neutrality from the geometrical center of the circle to a position closer to violet and blue.

His charts, from sections of the color solid, resemble the Munsell charts and go from white to black, through faint gray, pale gray, light gray, medium gray, dusky gray, deep gray, and dark gray; through tones, tints, and shades, to full chroma for each

color in the circuit. The system is presented in his book "The American Colorist."

The Munsell System. Albert H. Munsell, born in Boston, Massachusetts, in 1858, was an artist and art teacher. The Munsell color system is based on the idea of the surface-color solid, and the designation of colors includes hue, value, and chroma. Munsell's color solid is similar to that of Ostwald but more flexible and free to present colors in a truer relation. The core of the color solid is represented as a vertical pole showing nine degrees of lightness and darkness, from white on top to black at the bottom. Extending from this core, the various hues as presented in the color circuit reach out as far as they will go to full saturation. Each color does not reach the point of full chroma from the gray starting point in the same number of gradations. Thus while Ostwald's solid appeared as a regular geometric figure, Munsell's appears more like a tree, with branches extending all along the trunk in varying lengths. Directly opposite branches are complementary.

Munsell's color circuit includes yellow, green-yellow, green, blue-green, blue, purple-blue, purple, red-purple, red, and yellow-red, each occupying equal proportions and subdivided into 10 or more parts.

It has been found that color has dimensions—according to Munsell, three dimensions, which, if accurately given according to an established system, will clearly designate the color referred to. By reference to "The Munsell Book of Color," you will find the color as quickly as looking up a word in the dictionary. Suppose that your specifications call for R $4/12$. R stands for red; $4/12$ indicates that the red has a value of 4 and a chroma of 12.

The three-dimensional concept of Munsell hue, value, and chroma is identifiable with the psychological and psychophysical concepts used in colorimetry. (Psychological hue, lightness, and saturation; psychophysical dominant wave length, luminous reflectance, and purity.) Because of this and because the scales of Munsell value and chroma are the same for all hues, it is a most practical and useful system. With a reasonable amount of study and practice, the average person might conceivably learn to identify many colors from the notations, without reference to the charts. This system could be the basis for a universal language of color.

A. H. Munsell died in 1918, the year that the Munsell Color Company was formed.

Measurement

Since there are a great many color differences that are distinguishable by the human eye and there is need to match them, machines have been developed to do this work. A color atlas could not possibly include samples of every possible color. When a very accurate match is required, the sensitiveness of the human eye varies too much to be useful. For such a match, an exact kind of illumination is required. Machines such as are now in use easily and accurately detect over 2,000,000 variations of color.

The manufacturer is concerned about his product's yielding the color perception desired by the ultimate consumer. There are several degrees of whiteness, for instance. The manufacturer of bathroom fixtures produces a line of tubs, stools, bowls, etc. The consumer requires a new fixture and wants it to match the others that he has. To satisfy the consumer and to control the quality of products, standards have been established, and such standards are maintained by specifications developed by light-measuring and comparing machines. The manufacturer of American flags must conform to the color standards for flags found in the Federal Standard Stock Catalogue.

The spectrophotometer measures the reflecting properties of the specimen. It compares in spectral composition the radiant energy leaving an object with that incident upon it. Until recently, observations were made with this machine by man. It was an extension of visual matching, and the process involved various steps and took hours for the completion of an examination. Spectrophotometers are now made that operate automatically, producing color charts very quickly and with great accuracy. A beam of white light is dispersed into a spectrum by a prism. One narrow band at a time is reflected by a mirror. The color beam is split in two just in front of a target chamber. One beam is aimed at the standard white reflector in a box and the other at the sample under test. The photocell compares the reflectance intensity of each.

Numerous manufacturers of light-measuring equipment are listed in Thomas' Register of American Manufacturers. See spectrographs, spectrometers, spectrophotometers, spectroscopes.

The spectrophotometer is a combination of two optical instruments: (1) a photometer, to measure the fraction of the incident beam that is transmitted by the specimen, and (2) a spectrometer, which disperses a beam of light into a spectrum, usually by means of a prism.

Such machines can reveal color differences that are imperceptible to the eye. The color of a piece of glass is expressed by a curve indicating the transmission at each wave length. The color of a surface is expressed by a curve plotted on a graph, indicating the reflectance at each wave length.

A goniophotometer determines the angular distribution of radiant energy leaving an object. This reveals its glossiness and transparency. A spectroradiometer measures the radiant energy at different wave-length bands.

The scientific measurement of color requires a standard light, a standard background, and a standard observer. All three are provided in the modern machines used for this purpose.

Two colors that match under one illumination may not match under another illumination. These colors may have the same dominant wave length, the same percentage of brightness and purity, yet not match physically. Two colors that match physically, which reveal identical reflectance curves, will always match under any conditions.

Acknowledgment is given to the following sources of information. See also Part Seven.

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PART FIVE

Colors for Everyone

17

APPAREL

Before the dawn of civilization, man adorned himself with colorful shells, feathers, and other ornaments as he found them. In the early civilizations of the Mediterranean, the Far East, and the Americas, man wore colorful costumes. During the Middle Ages in Europe, both sexes continued to wear gaily colored apparel. In our country in colonial times, men and women wore garments that reflected a variety of greens, buffs, purples, yellows, and other colors.

In modern times in this country, women continue to display in their dress many variations of all the colors of the spectrum; but men, with few exceptions, have adopted a sort of uniform, appearing in blue, brown, gray, or black. There are sufficient reasons why men's suits are of subdued colors and why they will remain so for some time. In the meantime, men display their fondness for color in their shirts, ties, socks, etc. The average man does not like to attract attention to himself. He avoids being different from the majority and fears to appear ridiculous. Women are no less concerned about the opinions of their neighbors, but their tendency is to be different to some extent. They often strive for a degree of originality in order to attract favorable attention.

Only a few years ago, most men's and women's bathing suits were black. Now they reflect all the colors of the rainbow and enhance the vitality and spirits of the wearer. One might suggest that the use of color and fine fabrics is feminine and incompatible with masculinity, but the history of costumes does not support such an idea. The most manly men and the roughest, toughest, and most vital characters of history frequently have clothed themselves in brilliantly colorful costumes. Today the sportsmen, college students, and those associated with the stage and the screen—men who are generally active, full of nervous energy, alert, progressive, and vibrating with life—are inclined to use more color than do most men in other fields.

The formal black and white of masculine evening wear has much in its favor, but its charm is due chiefly to texture. The smooth hardness of the collar and the shirt bosom, the softness of the suit fabric, accented by the lustrous silk stripe and lapels and the brocade of the vest—all contribute greatly to the general effect. This ensemble serves effectively as a foil to the woman's colorful costume, but effects of much greater vitality could be achieved by using color for both. Male evening clothes in color are, indeed, being made and worn now, but the departure from black is very cautious.

In various parts of the world it has long been the custom for men in government service to wear silk waistbands (in place of waistcoats) with the regulation black or white dinner jackets. The color of the band depends on the branch of service in which the wearer is engaged. The practice has been adopted in this country by men in all walks of life, but here the color of the band usually has no significance beyond that it is the choice of the wearer. A gloriously colorful spectacle is a gathering of military officers and their ladies at a formal function. The colorful costumes of the ladies lose nothing by contrast, and there is no discord because each ensemble is a harmonious unit.

In the application of color to dress, the same rules and suggestions apply as in the case of any design or composition of harmony. Harmony, as always, depends on unity, consistency, arrangement of colors and areas with relation to form, and fitness to purpose and personal preference. As regards dress, professional stylists have some influence on public preference of colors in general. A color that becomes popular during a certain season, as a result of the efforts of such designers, may or may not have any lasting appeal. Men and women both are inclined to emulate the practices of others whom they look upon as more interesting than themselves. Thus if a movie celebrity in this country or a member of royalty in some other country appears in some new color or combination, less spectacular mortals tend to follow suit as best they can. The best informed individuals will, however, continue to choose the colors that best suit them personally and will give little attention to popular or passing fancies.

Any color or combination of harmonious colors can be worn

by anyone on certain occasions. The hues themselves are not so important in dress as are their qualities, such as purity and brilliance. The proportions in which they are used and the arrangement of the masses also require careful consideration.

Any color that is worn solidly, if unrelieved by some variation of hue, purity, or brilliance, results in drabness and monotony. A variation of texture alone would relieve the monotony to some extent. An example of this is found in men's formal evening wear. The satin facing of the lapels on the dinner jacket relieves the dull cloth of the body. Fur or velvet trimming on women's coats serves the same purpose. A monotone can be monotonous or it can be interesting. Contrast of some quality effects the change. A brown may be pleasantly relieved by yellow, orange, or vermilion, or even by variations of brilliance in brown alone.

Attention will be directed to the area or spot where the greatest contrast occurs. As it is desirable that the attention be directed to the face and especially to the eyes, the greatest contrast should appear high on the costume, near the face. For men this contrast is provided largely by the necktie and the pocket handkerchief. The face itself provides considerable contrast. The white eyeball, the iris and the pupil of the eye (with its high light), the skin, eyebrow, and hair are all usually contrasting in brilliance. Women accentuate this contrast by using cosmetics.

Because of the association of high lights over the pupils of the eyes, two bright spots on a dark background are the most compelling attention-getters that can be devised. Thus two bright spots of white or yellow placed close together on a dark dress, near the face, are very effective for this purpose. Jeweled clips serve admirably. Being placed high up, this contrast also serves to make the figure seem taller and more slender. A strong contrast between skirt and blouse or coat and trousers draws the attention low in the body, making the figure seem shorter. Vertical stripes or folds lend height to the appearance of a figure, while horizontal stripes have the opposite effect. Dark blue and other receding colors tend to slenderize, while orange and similar advancing colors have the opposite effect.

Unless the wearer is acting the part of a clown, pure colors in large amounts tend to subdue personality. Very dark colors make

the skin appear lighter, and very light colors have the opposite effect. Similarly, very warm colors make the skin appear less ruddy, and very cool colors produce the opposite impression. Skin and hair that contrast greatly (black, gray, and white hair) are most pleasantly supported by colors that are more pure and less brilliant, and that offer contrast. On the other hand, skin and hair that contrast very little (yellow, brown, and medium-red hair) are better supported by colors that are less pure and more brilliant, and that contrast very little.

There are hundreds of thousands of colors and combinations that any one might wear successfully. It is safe to say that any color, if used in certain proportions, shades, tints, and tones, and under certain conditions, can be worn effectively by anyone. Your most useful prescription for color would be made for you personally, not only your general appearance but your personality, interests, and preferences being taken into consideration. Attention should be given as well, to the environment in which the colors are to be worn and to the function of the costume, among other things.

The most informative work on the subject of dress for men and women that has come to this writer's attention is "Color and Design in Apparel," by Bernice G. Chambers. It is a book that you should read—one that, after reading, you will want to own.

The following general statements concerning each family of color should prove useful for the guidance of each individual in selecting colors to wear. Everyone who has a preference should know the limitations of the preferred color, should study its qualities and character, and should learn in what form and manner it can be used with the greatest satisfaction.

Black. Black tends to make a pale skin appear paler and white hair whiter. Because it is neutral, it can be worn safely by anyone, either alone or with color. It may be lively or dull, according to the texture of the fabric, and the fabric and the wearer should harmonize. Black is associated with maturity, age, death, wisdom, sophistication, seriousness, etc. In spite of these associations, however, some very charming costumes are created in black. It furnishes a very effective foil for attractive skin, hair, and accessories. Black (with high lights) lends dignity and is most

effective when relieved with some white and accompanied by a small amount of fresh color. As it tends to emphasize wrinkles in a dark skin, black is not very satisfactory for thin, dark, or sallow types; but it is dramatic and effective for blond women who have good color. It tends to make the body appear smaller. Although black combines well with most warm shades, it is not good with dark brown.

White. Although white is essentially neutral, it becomes warm or cool as it is affected by the surrounding lights and reflections. It may be worn by anyone, but will prove more or less attractive according to the colors that accompany it. Flat white is least pleasing with gray hair or a pallid complexion, although a lively white goes well with gray hair. White harmonizes best with cool tints, but enhances black hair and rosy cheeks. It combines well with light, vivid, cool colors and is satisfactory for most complexions except dark brunettes, whose darkness it accentuates. White is associated with youth, innocence, purity, etc. Nevertheless, the clever designer can create very successful costumes in white for more mature and sophisticated persons, although the effect is somewhat artificial. White garments tend to increase the apparent size of the wearer.

Gray. When it is neutral, gray accentuates any color that adjoins it. Light gray is least pleasing with darker gray hair. Dark, neutral gray is not for youth; but very light gray is more lively than very dark gray. Neutral gray harmonizes with any color, but the combination is best when the value of the two is related. Gray makes clear skin appear clearer and brown hair seem browner, but a dark gray tends to accentuate pallor. Gray combines well with most colors and is at its best when used with some color. Its most pleasing combinations are those with warm colors. Gray with accents of pure color is especially attractive for one who has fair skin and dark hair. A medium gray is good for a redhead.

Red. The most exciting color of the spectrum is red. Someone has said, "Wear red when you feel blue." Dark red and dark violet-red can be worn by almost anyone. Pure and brilliant red can be worn more effectively by darker and smaller persons than by lighter and larger persons. Pink, which should be worn only by the fair and the young, should be less bright than yellow hair.

It is a favorite color for baby girls. Scarlet and crimson can be worn effectively by platinum or ash blondes with fair, rosy skin. Red is a gay and youthful color—one that lends life to the wearer.

Red detracts from the beauty of red hair, but it is friendly to a florid or a dark face. A strong red is never suitable for redheads. Dark red (maroon and wine) is becoming to dark brunettes, as red adds fire to brown or black eyes and life to brown or black hair. A wide range of dull or grayed reds can offer some shade that is suitable for nearly everyone. When the color is grayed, pink is generally suitable for all types, but it is especially pleasing when used by pale blondes. It combines well with black and with many darker blues, greens, and reds.

Orange. When it is pure and brilliant, orange is hard to wear. However, in shades approaching brown, it is suitable for a dark, warm complexion; and in tints approaching yellow or pink, it is more suitable for delicate blondes. In small quantities it will lend richness to a cool ensemble. It can be worn effectively by the vivid brunette, and in grayed tones it goes well with gray hair. It is effective when combined with brown and with white, but it does not combine well with black or with bright blues or purple, in wearing apparel.

Brown. Dark, warm brown is a becoming color for warm brunettes and light brown, for warm blondes. Light tan or dark, cool brown is a good choice to be worn with black hair or with light-blond hair. Brown is not very satisfactory with white or gray hair, or with black hair when the skin is very fair. If it is worn with brown hair, the brown should be darker or lighter than the hair, rather than of the same value.

Brown conveys an impression of fresh, out-of-door sportiness, and is more suitable for the young than for the old. It is not a good choice for a sallow brunette. Reddish brown is not becoming to the redhead who has a ruddy complexion, but dark brown can be worn effectively by a fair or pale person who has brown or black eyes. Some dark browns do not combine well with dark blues, and reddish browns do not combine well with purple or with bright red. Brown goes well, however, with a smaller amount of bright green, brilliant blue, gold, coral, or orange.

Yellow. This is a difficult color for the average white person

to wear in large amounts. In full strength it is suitable only for accents and even then would probably look better if grayed. In its tints, yellow can be effectively worn by fair blondes. It tends to reflect its color on the hair, eyes, and skin, when they are dark; and it may make the skin of a drab blonde appear yellowish and the hair greenish. Brunettes appear better in the deeper shades and soft, dull yellows are best in any case. Some light, grayed greenish yellows are very attractive when they are worn by certain blondes or by those who have gray or white hair. Yellow creates a youthful effect.

Green. In the proper purity and brilliance, green can be worn by anyone. It complements and emphasizes the warmth of skin and hair. Dark green is better for brunettes and light green for blondes; cool greens for cool complexions, and warm greens for warm complexions. Large amounts should be broken (grayed), while small amounts can be kept purer. Unless it is much grayed, green is least attractive with white or gray hair. Dark blue-green may accent blue eyes, and dark brown-green may accent brown eyes. Brilliant green in any considerable amount does not give a pleasant impression when worn by anyone. A deep, rich grass green can be worn with satisfaction by most persons, but olive green, unless it is considerably grayed, is satisfactory only for those who have natural auburn or henna-dyed hair. Green combines well with white, brown, beige, grays, and warm colors. It accentuates the color of red hair, but the contrast can be theatrical. There is a green for everyone.

Blue. When worn by blondes and by those who have cool complexions, blue is at its best. Light blue should be reserved for cool, fair blondes. It is favored, too, for baby boys. Dark, soft (grayed) blue is attractive with white or gray hair. If it is worn by a warm brunette, this blue should be combined with a warm color. Purer blue can be worn with black hair and fair skin and is also suitable for platinum blondes. Blue, unless it is a greenish blue, makes red and yellow hair seem more yellow. Darker blue accents lighter blue eyes, and light blue may increase the yellowish appearance of the skin. In most cases dark blue is better, and dark greenish blue is best.

Deep grayed blues are good for the vivid blonde; purplish

blues and greenish blues for the redhead; soft blues for the medium blonde; stronger blues for the vivid brunette; and navy blue for the pale, blue-eyed blonde. Blue should be grayed for the redhead. Midnight blue, which under artificial illumination looks blacker than black, is being generally used for men's evening wear. It is more becoming than black. Navy blue is not so becoming to those who have brown eyes or red hair. Dark blue gives the skin a clearer appearance and does not rob it of color; it also tends to make the body appear smaller. Dark blue does not combine well with brown, but it makes a pleasant combination with most other colors.

VIOLET AND PURPLE. Light violet and purple-red or purple-blue are difficult to wear. Very light blondes may wear cool lavenders. Dark violet and purple can be worn by most persons—in purer quality when the hair and skin contrast most, and grayed when less contrast is found. Dark purple gives a rich effect with white or gray hair. Dark reddish violet is a color for maturity, while bluish violet and lavender are more suitable for youth. A pure, brilliant violet would not enhance a drab blonde, but a dark reddish violet might do so; a platinum blonde, however, could wear a purer violet with pleasing effect. A strong purple tends to make the skin appear yellowish. Violets and purples are not friendly to redheads, but they are satisfactory for blondes, blue eyes, clear brunettes, and gray hair. While these colors do not combine well with blues and black, they are agreeable when used with browns, grays, grayed warm tints and shades, and lighter greens.

Almost everyone is concerned with the problem of selecting color schemes to fit his or her individual personality and to set it off to the best advantage. Investigators agree that as a rule the most becoming colors are those that accentuate the beauty of the eyes, the hair, and the skin. Any color that dominates is faulty. The entire ensemble must be pleasing.

A general rule that applies to almost everyone is to avoid harsh colors—rich purples, brilliant greens, pinkish blues, and maroonish browns. They will do you no good, no matter what color your eyes and hair are.

A reasonably safe guide for dress is "like to like; warm with warm, cool with cool, dark with dark, light with light, and pure with purity and contrast." The relative brilliance of the colors

in any ensemble should follow the natural order; that is, the blues in the ensemble should be darker than the greens, yellows, and oranges in it. Likewise, violet should be darker than anything else used with it. Since red hair is beautiful, it should be accentuated, and this is an exception. Cool, dark colors are best with it. Brown hair may be so indefinite that the effect may be better if the hair and the costume do not match. If brown is worn, there should be a contrast of brilliance. Shades are more fitting for maturity and tints for youth. Small, bright dots on a dark field, like daisies in a meadow or stars in the sky, create a feeling of ecstasy. Thus polka dots and happiness are companions.

To choose the right colors with the right qualities and to combine them in the right proportions is no easier than it is to produce any other harmony; but such an achievement gives the wearer a sense of well-being, increases his confidence and efficiency, and makes him or her a pleasanter person for others to deal with. One's colors should be as personal as the timbre of his voice or the movements of his body. The function of color in dress is to enhance the natural beauty and good qualities of the wearer. The dress is intended to attract attention not to itself, but to the wearer. The beholder should feel inclined to say, "How beautiful you look in that dress!" or "You are more beautiful than ever in that dress"; not, "What a pretty dress you are wearing!"

Although jewelry usually occupies a very small area in the ensemble, the colored jewelry that is worn should be such as will contribute to the pleasantness of the whole rather than detract from it.

Some colors are finding favor for men's wear at formal functions, such as, dinner jackets in maroon, green, plum, blue. Along with these are seen colored waistbands or vests and colored ties. An attractive ensemble to be worn in our tropics is a gray or a tan dinner jacket with black or midnight-blue trousers, a soft white shirt, ruby studs, a maroon bow tie, and a red carnation on the lapel. Youth feels that it can be more joyful and lively in colors than in black and white; and age welcomes appropriate colors, to let all know that it is still quite among the living.

The Men's Fashion Guild of New York has conducted a number

of campaigns to encourage men to harmonize more effectively the colors of their suits, shirts, hats, socks, neckties, handkerchiefs, garters, suspenders, and cuff links. The first coordinated color combination to be attempted in the men's wear industry was presented in various retail stores in the spring of 1945. About 100 articles of men's wear were shown in two color themes, blue and gold.

Anyone who has seen a formal gathering of military officers and their ladies knows what a grand and lively spectacle they present. Seen at such a gathering may be a dark blue coat with vermilion lapels and gold trimmings, together with lighter blue trousers that have broad vermilion stripes down the sides. With this is worn a white vest, a white stiff shirt and collar, and a black bow tie. Other ensembles may include golden-yellow lapels and trouser stripes of the same color, or silver white or some other combination. For man to use color in apparel is in harmony with nature. It provides a valuable tonic for the soul and is good to look at. Learn what colors benefit you. Combine them according to the rules of harmony and wear them with satisfaction The costume should be a harmony in itself and then should harmonize with the wearer.

Acknowledgment is given to the following sources of information. See also Part Seven.

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18

BUILDINGS

Exteriors

From earliest times man has used colors for the decoration of his dwellings and of his public buildings, both inside and out, as well as for his apparel. Ancient architects, especially in western Asia, Greece, and Egypt, used color exteriorly as an important factor in design. The function of color in their scheme was not simply to liven up an otherwise drab structure, but to emphasize its line, form, and proportion. The Greek temples of two thousand years ago were not plain white structures. A considerable amount of strong and well-chosen color was employed by the architect. That color, which was applied to the marble, has in the course of years largely disappeared, because of its impermanent nature. The colors applied to ancient Central American temples, however, have in some cases persisted through the years and are still in evidence among the ruins.

For centuries architects of Europe and America have been trained in the symbolism of form based on the ideas developed during the Renaissance. Color has been practically ignored until recently, but throughout our country there are many examples of effective use of color on the exteriors of later-day public and private buildings. So far, however, in the majority of these instances the color is purely decorative and not structural. Where the materials used are of a permanent nature, the color will remain in evidence as long as the building stands.

In building exteriors, as in the case of any other composition embracing color, surface texture is important. Marbles and natural and fabricated stones of various colors are procurable. Colored concrete and stucco, glass, mosaics, metals, metallic paint, varicolored bricks, glazed and unglazed tile, etc., provide variety in texture. The vision of Manhattan from an incoming steamer on a bright day is impressive because of the proportions of the buildings, but

how much more brilliant it could be if the sun were reflected from more colorful and interesting surfaces.

A building should be a harmonious unit in itself, but it should also be so related to its fellows that the entire community shall present an effect of harmony. When men have grown accustomed to seeing cities, towns, and villages from the air, this matter will demand more attention. The general public will become more conscious of color, and the individual more alert to see and appreciate a satisfying use of color anywhere.

The architect will observe the same general rules of harmony in color as any other designer. The colors used will be harmonious with each other and with the surroundings and will be consistent and appropriate to the form, size, and function of the edifice. A building that displays harmonious colors attracts favorable attention and appears proud, friendly, and alive.

A discouraging factor that checks progress in this direction is the soot and dust abounding in most of our metropolitan areas. With improved methods of fuel consumption and smoke control and an increased use of electricity, or perhaps with application of atomic energy, this undesirable element may be removed.

The Gingerbread Castle for children, at Hamburg, N.J., is an extreme example, but one that carries out its purpose successfully. The turrets and towers and decorative figures done in colored concrete delight children and grownups, too. The American Radiator Building and the McGraw-Hill Building, in New York, represent two interesting and quite different types of the more conservative use of exterior color. The entrances of many buildings are decorated with colorful mosaics such as can be seen at Rockefeller Center in New York and on the reptile house in the Zoological Park, Washington, D.C. The terrazzo esplanade of the Adler Planetarium in Chicago, while it does not represent color applied to a building, is an important part of the whole plan. Here the "Cascade of the Months," with a thin sheet of water covering it, displays the signs of the zodiac and other designs in about 50 colors, providing an attractive approach to the building.

The possibilities of the use of color on the exteriors of buildings were dramatically demonstrated at the New York World's Fair in

1939, called "The World of Tomorrow." In this instance, paint was primarily the color medium adapted, since the transient nature of the project did not justify the use of more expensive or durable material. The following news item appeared in *The New York Times*, April 25, 1938.

The color scheme for the 1939 World's Fair, the result of two years' work by experts, was disclosed yesterday by Grover A. Whalen, president of the fair corporation. The main exhibit area will be of rainbow hue.

The World's Columbian Exposition in 1893 popularized classicism, said Mr. Whalen. Architecture followed in its footsteps for years. We anticipate that the New York Fair will popularize color in the same way. It will make people demand color in their cities, just as they now demand color in their kitchens and bathrooms and clothes. They will insist on brightening up the drab surroundings to which we have all become accustomed.

Fairs of the past have been for the most part "white fairs," or else color has been used falteringly or without much regard for effects in mass. We are taking two revolutionary steps in this fair. We are taking off our kid—or rather our rubber—gloves and are plunging both hands deep into paint pots.

We are also establishing a definite color plan, which will produce exciting but pleasing vistas of color everywhere one turns. Visitors will get a color cocktail wherever they go. It will be a revelation of what can be done with color in architecture. Nothing like it has ever been done before.

As an indication of what the fair will do with color, it was announced that two completed exhibit buildings would be painted for the preview to be held Saturday. The Hall of Business Administration will have its walls tinted white and yellow in two shades, with accents of vermilion and gray-blue. Its interior court will be done in deep red, violet, white, gold, and black.

The Hall of Communications will be painted two shades of yellow and white with accents of vermilion and blue-green. In contrast to the white façade of the structure will be the red-orange, blue, and white of its two entrance pylons.

The fair's prismatic color scheme was developed by Julian E. Garnsey, the board of design's color consultant. Others who took part in working out the plan were Ernest Peixotto, consultant mural painter, and Bassett Jones, consultant on lighting. It was Mr. Peixotto who devised the rainbow motif.

The perisphere and trylon at the fair's Theme Center will be white. From the core of the exposition three avenues, the Golden, Red, and Blue Avenues, will radiate. Buildings near the Theme Center will be painted in pale shades, with the color deepening farther away. Around the edge of the fan from the Gold through the Blue to the Red Plaza will run "an avenue of intense color—the Way of the Rainbow."

Mr. Garnsey explained that a total of 499 carefully graduated colors will be available to architects.

One of the nine gateways to the Fair, the Corona Gate North, was in an area of orange, exhibiting many shades and tints of this color accented by yellow, green, and red.

One of the many exhibit buildings was the Glass Center Building, constructed almost entirely of glass and including a tower of the same material. Its general color was pale green, accented in deep blue.

Although it may be many years before our great cities will take on color in so general a way, it is reasonable to suppose that more and better color will soon be in evidence on private houses. An attractive house of modern, flat-roof design might be developed in the following scheme. The structure is of grayish-magenta stucco supplemented with gray-buff fabricated stones on each corner, from ground to roof and around the entrance (without a porch). On the bluish-gray stone steps at either side of the entrance stand two large glazed pots, of deep blue. The door is in small black panels framed in dusky red, the whole door thinly framed in turquoise, with a black wrought-iron lamp having a red pebbled glass on one side of the entrance and, on the other side, a narrow window mostly covered by a heavy, oxidized-bronze, decorative grill. On the second floor, above the entrance, is a window, from which extends a black wrought-iron balcony just deep enough to permit the dark-blue shutters trimmed in turquoise to swing open or shut. There is a narrow band of buff to match the other stonework separating the lower from the upper story. The whole is surrounded by green grass and small firs, which contrast pleasantly with the general color of the building.

The exterior of a house may be as colorful as the owner wishes, provided only that it shall remain harmonious in itself and be kept

in harmony with the community. Hardly anyone would dispute the fact that a white house with blue-green shutters, a blue or gray-green slate roof, and a red brick chimney is more pleasant to the eye than a house that is white throughout. Orange tiles make a valuable contribution to the appearance of a white cement or stucco house and so does the green lawn surrounding it. In those parts of the world where sunlight is regularly strong, purer and more brilliant colors are favored. In the tropics one finds cement and stucco exteriors in a wide range of tints that harmonize pleasantly with roof tiles, foliage, and sky. Black wrought iron, glazed tiles, stained glass, awnings, pottery, shrubbery, flowers, water, etc., each contributes to the whole delightful effect.

Interiors

Color is applied to rooms to conserve light, to create a feeling of warmth or of coolness, to foster a mood, and to make life and work there more satisfying. A room whose walls, ceiling, floor, and furnishings are all white might conserve the light and offer the most satisfactory environment for certain types of work; but even such a room would not be entirely without color. As nature abhors a vacuum, so she abhors the negation of anything, including color. The only situation that is utterly devoid of color is absolute darkness. Any expanse of white is full of delicate gradations of color. In the white room mentioned, all the colors of the rainbow would probably be present and be visible to an observer of sufficiently sharp perception. While unrelieved white may be considered by some to be best for the operating room and the butcher shop, it meets with little favor for most other situations. Any color absorbs a certain amount of light, but sufficient light can be conserved while due consideration is given to other equally important matters.

As nature provides light from above, our eyes are constructed accordingly. Therefore sources of light and areas reflecting the most light should be above the eyes; otherwise the effect is unnatural and unpleasant. For this reason walls or ceilings, whichever are intended to assist in illuminating the room, should be of greater brilliance than any other large areas in the room.

The first step in the decoration of a room is to decide what the predominant color shall be. Is the room to be essentially red, orange, yellow, green, blue, violet, black, white, or gray? This will depend on many things. For instance, the function of the room will influence the decision. The library of an elderly gentleman, the nursery of a baby girl, the waiting room of a bus line, a courtroom, and the lobby of a hotel obviously will each require specific consideration. Even the dining room, living room, and bedroom of a single house require individual planning; possibly, also, the different parts of a single room. It would require a very large book indeed to make a study of many types of rooms and no book could competently cover all types. Even if this were possible, it would probably not be very useful.

It is hoped, however, that the information and suggestions offered here will help the reader to understand the principles of good interior decoration for any type of room, give him the confidence to create his own compositions, and guide him to be critically appreciative of the works of others.

A furnished and decorated room is not essentially different from any other composition of color. It has the same general elements as a costume, a painting, or some other design. It is harmonious when it observes and follows nature's color practices and has unity, balance, and fitness. Any living thing ordinarily prefers a moderately warm and adequately illuminated environment. Man does not like a temperature that greatly differs from that of his body, or light that requires him either to protect or to strain his eyes, or an environment that is inconsistent with its purpose.

If sunlight is relied on to provide illumination, it may be too weak or too strong, according to the exposure of the room and to other conditions. Good reflectors outside and inside help to make the most of whatever strength the light has. White or a very light tint of yellow is the best reflector of light. Thus a room that is low on a narrow court will suffer less from lack of sunlight if the court wall is painted white, and the most can be made of the reflected sunlight if the walls of the room are of a very light tint. On the other hand, a room may be so situated that it is exposed much of the time to the direct, glaring rays of the sun. Such light can be blocked off by shutters, blinds, screens, heavy curtains, etc.; but

sunshine is desirable and should not be shut out but only modified and rendered less irritating to the eyes. Greens and blues are useful for this purpose. Besides, it is reported that houseflies will shun rooms that are painted light blue.

Artificial illumination can be adjusted to any conditions or requirements and affords complete freedom for the use of any colors, as far as illumination is concerned. A dark situation requires the use of greater contrasts than a light situation. A well-lighted room can be satisfactory with little variation in brilliance in its decoration, but the darker room requires considerable variety.

Dark red-orange is associated in the mind of man with fire and heat; therefore the color creates a feeling of warmth, without actually raising the temperature of anything that it accompanies. Light green-blue, which is associated with ice and coldness, has the opposite effect. Thus a room in which warm colors predominate appears to be warmer than it actually is and a room in which cool colors predominate seems cooler than it actually is. As has been mentioned before, anything that pleases and satisfies man is definitely one thing or another; nothing is quite so disturbing as that which is doubtful. Equal quantities of pure red-orange and light green-blue in a room would contribute as little to its harmony and pleasantness as would the presence simultaneously of a bonfire and a load of snow.

If you could redecorate your rooms twice a year, the logical procedure would be to employ a warm color scheme in the winter and a cool one in the summer. The next best thing would be to use fairly grayed colors on the walls and, in the summertime, to change the warm draperies and rugs for cooler ones and to hide warm furniture under cool covers. A room supplied with warm decoration would appear smaller and perhaps more cozy than it would if decorated in cool colors. Texture is important in decoration. A fabric with a heavy pile gives a richer and warmer impression than would a smooth, hard fabric of the same color.

The color scheme may be a monotone, but it should avoid being monotonous. To create a pleasant feeling, colors must have some sort of contrast. Yellow is a useful color, and a room in which yellow predominates can be very attractive. However, in no case should yellow or any other color permeate every part. Nothing

can be appreciated if there is nothing else with which it can be compared or with which it forms a contrast. If the color scheme is predominantly warm, it is most effective when a small amount of cool color is present to give it an accent. Likewise, a "perfect" harmony can be made more interesting by the introduction of a small note of discord.

A public room, unassociated with dwelling, is impersonal and can be suitably decorated and furnished with one hue in various degrees of purity and brilliance. Among such rooms might be included waiting rooms, art galleries, courtrooms, offices, lavatories, shops, restaurants, hotel kitchens, etc. However, an individual or a family would find little satisfaction in living in such a room. Simplicity and unity are desirable in any situation, but they can be achieved without monotony. Variety is the spice of life, and some persons require more of it than others.

The ocean can comfortably accommodate many very different types of life, but if a dozen or so of those types were included in one small tank, they might be uncomfortable, to say the least. Likewise, contrasting colors can get along cheerfully together if they are not crowded. As analogous colors harmonize easily in close quarters, an analogous harmony is usually more satisfactory in a small room than a complementary harmony would be.

A small room will be more satisfying when the colors of the walls, ceiling, and trim are closely related in hue and brilliance. There is charm in simplicity. In some instances, the end walls of a large, rectangular room could be painted in a hue different from that on the side walls, but related to it. If the color of the smaller end walls is more advancing, this will tend to bring them closer together. Such variety also makes the general effect more interesting. The ceiling of a large room has sometimes been painted a darker color than the walls. Since this does not follow natural order, the effect is unusual and may be interesting; it is at least novel. Such a ceiling will appear to be lower than it actually is.

It is a good practice to use warmer colors in decorating rooms that face north and cooler colors for rooms facing south. In any case, careful consideration should be given to light, size, proportion, and fitness.

A series of rooms need not be decorated in the same color

scheme, but there should be a degree of gradation from one to the other, and the transition or sequence should not be abrupt. While man likes variety, he does not like to be jolted by it. The same combination of colors can be used satisfactorily in two adjacent rooms by reversing the colors on walls and ceilings.

In choosing furniture and rugs for a room, try for an effect of unity and harmony and a degree of simplicity. If the decoration is appropriate for "blond" furniture and you choose that type, the rugs, lamp shades, picture frames, etc., should be harmonious with it. If the furniture chosen is walnut or mahogany or any other dark wood and the upholstery is rich and dark, the rugs and other accessories should correspond. The very dramatic effects that can be achieved in very modern interiors are successful in proportion to their appropriateness and their harmony with the personality of the individual who is to use the room. Every man and every woman has personality and the home environment should reflect and enhance that personality.

One's choice of pictures is usually revealing as to the personality, culture, and interests of the individual. Pictures have always had a place in most homes and probably always will have. The basic function of a picture in the home is to decorate a wall and contribute to the charm and agreeableness of a room. Photographs, etchings, drawings, prints, and paintings all have their places and their values. The subject matter chosen frequently reflects the person's special interests in life; however, a picture may be chosen simply because it is interesting and good to look at.

Aside from subject interest, the main consideration in the selection of a picture is whether or not it is an attractive wall decoration and one that enhances its surroundings. No picture should be such a realistic representation that it "makes a hole in the wall." It should not give the impression of a scene being looked at through a window or, if it is a portrait, of the subject's being physically in the room. A picture must always be recognized as a work of art and not as a substitute for the subject matter. A great part of the charm and value of any picture lies in the artist's contribution, his use of colors and his manipulation of paints. The artist is not intended to copy nature but is expected to be inspired by some subject, experience, or thought and to create a composition that will

reflect his impressions. Pictures are friends to live with, to know, to love, and to form part of our lives.

Thus the planning of an interior calls for consideration of its illumination, of those who will be using it, and of the purpose for which it is intended. A maximum illumination could easily be achieved by means of white walls and numerous strong sources of light, but a consideration of the occupants and their activity calls for color. The very least that correct colors can do in an interior is to create an atmosphere that is attractive, pleasant, comfortable, and agreeable. By imparting these qualities to a room, color accomplishes many other ends.

The brightly illuminated room does not require strong contrasts of color, whereas the room with dim lighting does. Bright illumination is cheerful and inspires action, whereas dim illumination is sober and restful. The approximate percentages of light that walls of various colors will reflect is given here:

Color	*Percentage*	*Color*	*Percentage*
White	85	Light blue	55
Light ivory	80	Light pink	55
Pale yellow	70	Buff	50
Cream	65	Pea green	40
Light green	65	Steel gray	30
Light orchid	60		

A maximum of light should come from overhead, and a white ceiling is generally most effective in serving this purpose. However, there are many situations in which such maximum illumination is not required and in which a colored ceiling will contribute more to the attractiveness of the room than would a white one. While the walls should assist somewhat in the illumination, the main function of their color is to create the desired atmosphere. The warmer colors, suggesting warmth, are mellow and inviting; the cooler colors, suggesting coolness, are restful. A pale yellowish green or a pale reddish violet is normally neutral, neither warm nor cool. These tints may supply a warm impression in winter and a cool impression in summer.

Some good examples of the partial use of color in dwellings follows:

Living Rooms

White ceiling; yellow and gray horizontally striped wallpaper; yellowish-gray rug; yellow and gold figured drapes; yellowish-green loveseat; violet-blue sofa.

Ivory walls and ceiling; white venetian blinds; soft red-orange drapes and rug; orange-yellow sofa; chairs with yellows, grays, greens, and light-orange hues.

Ivory ceiling; light yellow-green walls; orange drapes; brown rug; furniture with variations of yellow, green, gray, and orange.

White ceiling; light green-blue walls; dark-blue rug; light-orange sofa; black and gold lamps.

Light-green walls and woodwork; dark blue-violet rug; cherry-red lamp; light-green loveseat.

Blue-gray walls; blue drapes; light-green and yellow rug; bright-green, yellow, and red striped sofa.

Light orange-yellow walls and woodwork; violet-blue figured drapes; dark blue-violet rug.

Coral ceiling; blue-gray walls; orange-red drapes; maroon rug; red sofa; orange chair.

Light-blue ceiling; deep-cream walls; dark-brown rug; red sofa.

Light-orange ceiling; light blue-gray walls; white woodwork; blue-gray rug; light-green figured drapes and sofa; light-tan chairs.

Light-blue ceiling; blue-gray walls; light-green drapes; purple rug; medium-green sofa; light gray-blue chairs.

Light blue-gray ceiling; light blue walls; grayish-brown woodwork; dark-blue rug; red-orange chairs.

Bedrooms

Light gray-green walls and ceiling; beige and blue rug; white bedspread; salmon chair.

Light-pink ceiling; two walls, solid rose; two walls, light-blue and rose striped paper; red rug; mahogany furniture; medium-blue chair and bedspread.

Coral walls and ceiling; white woodwork and venetian blinds; gray-blue rug; light-orange and blue drapes and bedspread.

Light-cinnamon ceiling; darker cinnamon walls; white woodwork; light yellow-green painted furniture; dark blue-violet rug; yellow-orange drapes and bedspread.

Cream ceiling; part of walls, tint of grayish red; rest of walls, light green; white drapes, woodwork, and bedspread; orange-yellow rug.

Cream-gray ceiling; light green-blue walls; medium-green drapes; brownish-gray rug; light-tan furniture; salmon bedspread.

White ceiling; peach walls; light-brown rug; orange bedspread; orange and brown drapes; dark furniture.

Entrance Hall

Light-gray wall; white ceiling and woodwork; dark-blue floor and stair steps; light-blue rug.

Ceiling and one wall, grayish pink; other wall, light bluish green; dark-green rug on floor; light-red carpet on stairs; ivory woodwork.

Grayish-pink ceiling; light-orange walls; light-green woodwork; greenish-gray rug and carpet.

Light-buff walls and ceiling; dark-brown baseboard and woodwork of stairs; red-brown carpet on stairs, carried around border of rug on floor; middle of rug, dark greenish-yellow.

Kitchens

White ceiling; light greenish-blue walls, with accent of orange; black floor, with accent of green-blue; white fixtures, with small accent of orange.

Light-green walls and ceiling; ivory cabinets and woodwork; dark-blue floor; white fixtures, with small accent of blue.

Light-green ceiling; light-orange walls; black working surfaces; brownish-green floor, with black border.

Deep-yellow ceiling; light-gray walls; white fixtures, sink top, and cabinets; medium-blue working surfaces; dark-blue floor.

Bathrooms

Light-orange upper walls and ceiling; light-green lower wall, accented with black; green floor, with black border separated by orange stripe; light-turquoise fixtures; orange drapes.

Light-green upper walls and ceiling; deep-cream tile and fixtures; light-yellow woodwork; orange-yellow drapes, with accent of black; black floor.

Ivory ceiling; light-green walls; white fixtures; black receptacles; deep orange-pink tiles around tub, outlined in black tiles; dark-green floor.

Light yellowish-green ceiling; white upper wall, separated from lower by yellow band going around window; lower walls, light grayed orange; white fixtures; light-gray floor, accented with light green; light-green curtains.

Greenish-ivory ceiling; peach walls; light-blue fixtures; tan floor; light-orange drapes; yellow bath mat.

Schools

The function of the school building is to provide a suitable environment for teaching and learning. Color can aid in creating an environment that will help both the teacher and the learner.

The first consideration in a classroom is illumination. Adequate and desirable reflection is provided with walls and ceilings painted in light colors. The colors are necessary to make the room attractive, agreeable, and inviting. Classrooms, study halls, and workshops should in general have a very light ceiling, medium-light walls, and medium-dark floors. A good ceiling color is a light rose. The most suitable walls are of light greens and grays. A desirable effect is produced by coloring adjacent walls in different tones of the same basic hue. Floors of brown or green are most suitable for study rooms. The lobbies and halls of schools should generally reflect a feeling of youth and progress. There is no place here for drabness. Various combinations of buffs, greens, blues, browns, reds, etc., can be combined with pleasing and interesting effect for this purpose.

At a recent meeting of the National Education Association, Miss Alice Miel, Columbia University education professor, is reported as stating that pale-yellow walls encourage study, brown walls for classrooms are undesirable and would make children drowsy, blue walls are cold and might give the child the idea his teachers do not love him. In her opinion, pale-green and pale-yellow walls provide the most suitable environment for children in elementary school.

The auditoriums, lunchrooms, gymnasiums, and other large meeting places should be in warm, congenial, inviting colors that make the students glad to be there. Colors of the auditorium would fittingly be more dignified and more generally analogous, whereas the lunchroom would call for more lively combinations to induce good appetite and digestion and, at the same time, give a feeling of relaxation. The gymnasium would display both contrasting and analogous tints, to keep it in harmony with the lively activities held there and to aid the vision of both players and spectators.

In any case, there is no one color or combination of colors that

is greatly superior to another. The desired results can be accomplished in any one of thousands of combinations; but whatever colors are used, they should be combined carefully, with due regard for the purpose intended.

In any situation possessing normal illumination, the following tints, gray tones, and shades are most satisfactory.

School Interiors

Tints: Yellow, yellow-green, green, green-blue, pink to red-orange, light orange.

Gray tones: Green, blue-green, red-orange, orange, yellow-orange.

Shades: Deep reddish or yellowish browns, deep greens and blue-greens, maroon.

Offices

Office workers will perform more efficiently when they can take pride in their environment, work in comfort, and have to endure a minimum of strain on their nerves. Color, when properly used, relieves eyestrain and creates an atmosphere that gives the worker a feeling of pride and happiness. Offices should appear attractive, light, clean, and orderly, but not cozy. The decoration should be simple and devoid of ornamentation.

White, ivory, or cream ceilings are hard to improve on. However, where variety of coloring is desirable, various light grays, yellows, greens, blues, and pinks are found to reflect a satisfactory percentage of light and are frequently employed.

Light grayish green or buff is, likewise, generally satisfactory for office walls, accented on baseboards and other trim by a darker analogous color. Green, gray, or brown floors, darker than the walls, are also most generally used. In case dados are used, the dado will be most satisfactory in a color analogous to the upper wall and of a lower value.

For individuality and charm the following are good color combinations for offices.

Office Interiors

Coral ceiling; light-turquoise walls; white woodwork; dark-brown floor; tan furniture.

Light blue-green ceiling; light-orange walls; dark-blue floor; red or orange chairs.

Light blue-gray ceiling; light but strong blue walls; dark-green floor; red or light-orange chairs.
Cream ceiling; light-green walls; brown floor; dark-green or orange chairs.
Yellow ceiling; blue-gray walls; dark-purple floor.
Light green-blue upper walls and ceiling; medium-green dado; dark-green baseboard; light-brown floor; orange or red chairs.
Light-gray ceiling; light grayed-pink walls; blue-gray floor with same, but darker, baseboard.

Adjoining walls in any interior can be most attractive, interesting, and eye-relieving when they are of different, but preferably analogous, colors that have been chosen with consideration for lighting and other factors.

The office of Personnel, Department of Agriculture, advises,

The Department has made use of various color combinations in the interior finish of offices for the purpose of improving lighting and preventing eye strain. There is evidence that certain combinations have reduced the number of office workers visiting the emergency room for eye treatments.

As many factors have a bearing on the final results of such experiments, such as seasonal changes, changes in types of work, and fading of the colors, a considerable period of time will be required before any appraisal of the results can be made.

Undoubtedly improvements in working conditions which aid vision will automatically raise morale and increase production.

Arthur A. Brainerd and Matthew Denning make the following statements in a paper prepared in September, 1941.[1]

In the average office area, we have white ceiling, buff walls, and brown linoleum on the floor. Desks and furniture are brown or mahogany. The whole combination is monotonous, and work is irksome. . . . One color was finally chosen which had an eggshell finish and a reflection factor of 85 per cent. This was adopted as standard for all office areas on Philadelphia Electric Company property. After three years' experience, we are still maintaining 26 footcandles with 4.1 watts per square foot, from an indirect lighting system. A companion side-wall tint hav-

[1] See "Plant Operation," Part VI, Chap. 20, of this book.

ing a reflection factor of 60 to 65 per cent was developed in a similar manner. The tint (buff) was decided upon, not because it produced better seeing, but rather because building management insisted on this shade for maintenance reasons. However, a light green side-wall paint with a reflection factor of 45 per cent was made standard for certain offices, and the results were quite successful.

This one improvement in office areas produced much better seeing conditions. Moreover, it was proved that adequate attention to quality of paint pigment ensures a maintained utilization factor considerably better than normal. The formula, which was originally intended to be an acceptance specification for Philadelphia Electric Company use, has since been widely adopted by our customers and various users throughout the United States.

This experience of added lighting efficiency and increased comfort suggested that a more extended study of the effect of surrounding surface colors and finishes on visibility might uncover much useful information. In an office, the ceiling becomes a very efficient and satisfactory secondary light source, so that proper tinting of the ceiling and side walls has a marked effect on healthy seeing conditions. The conditions here are much like an archery range. A proper color contrast gives an impression of depth and spaciousness, so valuable to a desk worker. The current practice of introducing color in desks and chairs helps to emphasize this feature.

Hotels

A hotel is a public building intended primarily to serve as the temporary home of persons who are traveling. It is also used as a permanent home by many who find it more suitable for their purposes than a private dwelling would be.

A hotel of the better class is a large dwelling place in which many hundreds of cultured and successful men and women live together for varying periods of time. They require not only a comfortable and attractive environment, but a great variety of services associated with food, lodging, and entertainment. To provide such service and environment that will satisfy thousands of different people is a big task, and color is an indispensable factor in the accomplishment of this task.

A first-class hotel provides an environment that is palatial. Everything is on a grand scale and in excellent taste, a result of the combined efforts of a multitude of specialists. The atmosphere

is one of rich, full, and successful living, wherein is reflected the spirit of welcome and hospitality, expressed to a great degree through color.

Any of the better hotels would undoubtedly serve as a good example of the use of color in this connection, but the one presented here is the new Hotel Statler in the nation's capital. Here the choice and use of color is modern, to accompany modern architectural design. It is attractive, dignified, and effective. Holabird and Root of Chicago, in association with A. R. Clas of Washington, designed the building. The Trylon Studios, a subsidiary of the Hotels Statler Company, Inc., developed the color schemes. The murals were painted by Edgar Miller of Chicago.

The exterior of the building is of Indiana oolithic limestone, sand finish, from the P. M. & B. quarries of the Indiana Limestone Company. The outside trim is of Swenson pink granite from Concord, N.H. The warm-gray exterior of the building is relieved by green terraces and hedges and two dark-red flagpoles.

In the lobby and on the second floor, where public rooms are located, two kinds of marble have been used—a light-buff variety, called "Fiorito (flowery) Auricinia," from Italy, and a gray to black marble with white markings, called "Balacet," from Belgium. The floors of the lobby are of black and gray terrazzo, accented at the front office by lighter areas extending from the desks. Both marbles have been applied solidly on the lobby walls. The walls and ceilings of the lobby corridors generally reflect a light greenish gray. Medium-green and dusky-rose rugs cover large areas of the floor. Great expanses of marble and glass; tall pillars of marble; exotic displays with lighting, frosted glass, and plant forms help to create a grand effect. Both direct and indirect lighting are used throughout.

The soft-gray plush chairs and the grays of the marbles and walls tend to enhance the coloring of the guests and their apparel; but the grays are relieved along one corridor by bright-yellow leather chairs and, here and there, by ferns and colorful flowers. In another corridor are white display windows, colorfully dressed and exhibiting varicolored articles, brightly illuminated. These are effectively accentuated by the surrounding gray walls.

The elevator foyer has a natural-wood finish, with large glass

mirrors. The elevator doors bear interesting red, white, and blue motifs; and the interiors of the elevators are given natural-wood finishes featuring different woods.

On the ground floor, the two main dining rooms have heavy glass doors. The Embassy Room, where entertainment is provided at night, has a grayish-rose ceiling and sand-colored walls above an undulating yellow-green figured panel.

The Veranda, which serves as a cocktail lounge in the afternoon, has a light-lavender ceiling and walls accented with yellow. The chairs here are of yellow leather and orange upholstery. A figured gray rug covers the floor.

On the walls adjoining the main stairway, which ascends over the entrance, are murals of stylized plant forms done in grayed-green tones. This stairway crosses an expanse of glass over the entrance, at the sides of which hang dark-green drapes.

In the second-floor corridors also there are murals by Mr. Miller, featuring realistic human and animal forms done in tones of red. Here the walls are generally warm gray and the floor is of light- and dark-gray terrazzo. On the entrance side, the second floor consists in part of a long balcony, overlooking the entrance and parts of the lobby below. Along this balcony are short, dark green-gray pillars. Light-gray marble is used here in parts, and warm-gray plush chairs and cream-colored leather sofas enrich the scene. Black and gray figured rugs cover most of the floor.

On this floor are several rooms in a variety of sizes for meetings, dinners, and other similar functions. The Presidential Ballroom is distinguished by the heroic white reliefs about its walls. This room has been so designed as to be especially adaptable to any scheme of decoration that might be temporarily desired. Such effects are usually accomplished by means of drapes, floral arrangements, rugs, colored lights, etc.

The larger rooms on this floor are enhanced by appropriate mural paintings. A variety of colors have been used for ceilings and walls and the general effect is one of richness and dignity.

The elevator doors on this floor are of dark blue-gray, with three large, contrasting disks of lighter blue-gray.

On the floors occupied by living rooms and bedrooms, the halls have cream walls and ceilings with black baseboard. The floors

are covered with dark-green figured rugs. The room doors are of natural-wood finish of a medium tone. Direct overhead lighting is used along the halls and indirect lighting beside the elevators. The elevator doors and frames here are of yellow-green, with three large contrasting disks of a lighter yellow-green. The "Up and Down" signal panel is of black and gold color. The "Up" indicator is in green, the "Down" indicator in red.

The bedrooms and living rooms are done in a variety of pleasant combinations, having a light, cheerful aspect and being appropriately furnished with equipment of modern design.

In the guest areas of the hotel on the street level, off the lobby is the men's bar, which has a dark-cream ceiling, dusky-red walls, red-leather chairs, and a brown rug. The walls bear small, appropriate mural decorations, individually illuminated. Back of the bar a large, well-executed mural painting contributes charm to the atmosphere. The barber shop, adjacent to the bar, has a cream ceiling and cream upper walls, a gray-marble dado, dark-blue leather chairs, and a gray terrazzo floor.

The coffee shop, which is below the street level and is reached by patrons from the lobby and from the street, is cheerful and inviting. The ceiling is in parts light cream and light gray. The walls are light gray. The table and counter tops are light-gray plastic, accented by a red border on the tables. Yellow fluorescent indirect lighting from behind the seats along the walls causes the walls to appear a soft yellow, and this color is also reflected from the ceiling, wherever the light strikes it. The floor is green in the center and dark blue around the sides, with a separating band of red. The chairs are of green leather. The white napkins have red and blue borders. The pottery water pitchers are of solid tints of yellow, blue, green, and orange. Numerous mirrors reflect the surrounding colors and the faces of the satisfied customers.

The "back of the house," which includes most areas used only by employees—halls, kitchen, bakery, laundry, etc.—generally displays cream ceilings and cream upper walls, a sand-colored dado of tile, a darker tan baseboard, and a red-tile floor. The laundry and the halls on the same level have uncolored cement floors. The steam tables and related equipment in the kitchen are gray; the refrigerator doors, of natural, polished wood. The engine rooms

have cream ceiling and cream upper walls, with gray dado and floors. In addition, in the engine rooms various bright, contrasting hues on various pipes and equipment are employed for purposes of identification.

Hospitals

General hospitals, as everyone knows, are establishments wherein a variety of human ills and damages are adjusted and repaired. The success of a hospital depends, among other things, on the skill of its staff, the excellence of its equipment, and the atmosphere that pervades it. In the creation of a desirable atmosphere, color supplements architectural design.

It is known that mental attitude is a factor in the recovery of sick persons. Properly applied color can influence the attitudes of both the patients and the attendants, thus contributing measureably to the success of the establishment.

For the purpose of revealing dirt, white cannot be surpassed. Since surgery requires utter cleanliness, and spotless white is apparent evidence of this, white has for centuries been associated with hospitals and surgeries. It has been favored also because of its light-reflecting quality, securing the best possible result from the illumination available. However, because modern methods and equipment ensure that such places and equipment would be clean and sanitary even if they were colored black, white is no longer needed for revealing dirt.

The artificial illumination now available does not require white reflectors to provide desirable light. Furthermore, white does not beneficially influence the attitudes of either patients or attendants, and thus cannot make a contribution of that kind to the efficiency of the attendants, the recovery of the patients, or the success of the establishment.

So color comes forward. It is found to be sufficiently dirt revealing and sufficiently light reflective, and it does definitely contribute to the desired ends of hospitals and similar institutions.

In a color scheme for a modern hospital presented by Faber Birren in "Functional Color," two tones of turquoise blue have been used (medium deep and pale), with tints of yellow-green, yellow, and orange (peach) to complete the choice of colors. In

his plan the operating rooms have white ceilings and deeper turquoise walls. He suggests that turquoise-colored sheets be used for operating, to relieve eyestrain. The service departments are of pale turquoise blue, which is cool and clean and complementary to flesh color. Corridors, reception rooms, etc., are of soft orange (peach), which is warm, bright, and cheerful. For the maternity division he prescribes peach and yellow—a combination suitable for an active environment. The wards are to be pale yellow-green and pale turquoise, to induce peace and relaxation.

To supplement these room colors, Birren suggests that the uniforms for nurses shall be blue; for doctors, internes, and surgical supervisors, white; and for floor maids and housekeeping personnel, pale green.

In choosing the colors to use in specific rooms of the hospital, consideration must be given to the purpose of the room and to what colors have qualities that will help best to serve that purpose. Waiting rooms should reflect a spirit of welcome and cheerfulness. A well-lighted room with ivory ceiling, deep-cream walls, medium-green gaily figured floor, and light-orange upholstered seats would serve. In halls, foyers, waiting rooms, and other general quarters, lightness and cheerfulness should be achieved. They have no other function than to be pleasant. For these such combinations as the following are effective.

General Quarters of Hospital

Ivory ceiling; light-yellow walls; light-gray baseboard; light-brown floor.

Ivory ceiling; light-green or light-orange walls; light-gray baseboard; light-brown floor.

Light-blue ceiling; coral walls; deep-violet baseboard; dark-gray floor.

Patients' rooms should be designed to help recovery, as the patient spends much of the time lying in bed with eyes on the ceiling. Such combinations as the following are good.

Patients' Rooms

Pink ceiling; light-peach walls; light-turquoise drapes; rose bedspread; yellow lamp shade; red-violet chair.

Light blue-green ceiling; light-lavender walls; tan drapes; turquoise bedspread; green lamp shade.

Ceiling and two walls light green-gray; two walls light orange; gray-blue drapes and bed spread.
Medium blue-gray ceiling; light blue-gray walls; pink-gray rug; yellow drapes and bedspread; deep gray-blue chair.

It is doubtful whether any combination is better for surgical rooms than white ceiling and turquoise walls.

Lecture rooms should be so planned as to focus the attention on the speaker, to rest his vision and that of the audience, and to appear inviting and comfortable. The wall behind the speaker and that behind the audience might well be of blue-green, the side walls of dusky rose, the ceiling of light blue, and the woodwork of light gray. More warmth could be effected with a ceiling of light yellow.

The solarium should make the most of the reflected sunshine. A good combination would be an ivory ceiling, light-yellow walls, orange drapes, light greenish-gray floor, and green and yellow chairs.

The newly constructed Naval Hospital at Bethesda, Md., offers many good examples of the use of color in aiding the recovery of ill members of that branch of the service. The building was designed by Frederick C. W. Southworth and Paul P. Cret.

The exterior of the building is of fabricated light-gray stone, accented by darker gray areas between the windows. The building, with its tall, stately tower, its grand approach, and the surrounding well-landscaped grounds, presents a beautiful and impressive sight.

The entrance hall is of green and gray, with a light-gray pebbled ceiling; light-green marble in the upper parts of the wall and darker green marble below, the two being separated by a strip of still darker green marble; and six-sided dark-green marble pillars rising from a light-gray terrazzo floor. There is a balcony enclosed by a balustrade, with green and chromelike metal strips. From the center of the ceiling above the balcony hangs a stainless-steel chandelier, of modern design. The elevator doors and frames are of stainless steel.

The corridors are generally given cream ceiling, light-tan walls with darker baseboard, and brown floor. The walls, in many corridors, have a dado of pink-tan tiles.

A large number of specially equipped workshops have been created to enable patients with a variety of abilities and tastes to engage in those activities that most appeal to them. These shops are painted in color combinations that are inviting, genial, comfortable, and conducive to good mental attitudes and early recovery.

A woodworking shop has a gray-green ceiling, one wall of medium green, other walls of yellow, orange baseboard, and brown floor.

An exercise room has the upper walls and ceiling in yellow and the lower walls in dusky red.

Other rooms have the following combinations:

Naval Hospital Rooms, Bethesda, Md.

White ceiling; light-green walls; darker green baseboard; brown floor.
Cream ceiling; upper half of wall light green; lower half dull red.
White ceiling; two walls green; two walls yellow.
Ivory ceiling; upper wall yellow; lower wall dull red; brown floor; woodwork dark green.
Ceiling and upper half of wall yellow; medium-green lower half of wall; brown floor.

The wards have ceilings of ivory and walls of cream with gray trim.

The laundry is of white and cream.

The mess-hall has white ceiling, cream upper wall, and darker cream tile lower wall.

The clinics have white ceilings, light-green walls, and light-brown trim.

The pharmacy has white ceiling and light-cream walls.

The new recreation building near by has the low, horizontal lines of modern architectural design. Its exterior is colored a reddish brown to contrast with the surrounding green foliage.

One of the toilets seen has light-yellow upper walls and ceiling with soft-green tiles below.

The kitchen has ivory ceiling, light-cream upper wall, and light-rose tiles below.

The women's lounge has light pinkish-brown walls and medium-purple tiles, on which rugs will be layed.

The men's lounge is done with greenish-gray walls and dark-blue tiles.

The gymnasium has warm-tan walls with orange trim, and the pool is in light green with dark-blue trim.

Some Color in the Nation's Capital

Most of the public buildings of Washington are of gray or white marble and designed along classical lines. They are masterpieces of architectural design. The lack of exterior color is compensated for by artistic landscaping, beautiful trees and shrubs, and in season by a profusion of blossoms and flowers of many colors. One exception to the gray and white rule is the Smithsonian Institution, which is of reddish-brown sandstone, done in the Romanesque manner.

The center building of the United States Capitol is of Virginia sandstone, painted white; the extensions, of Massachusetts marble. The statue of Armed Liberty on top of the dome, measuring 19½ feet in height, is of bronze, which has become oxidized. At night, when the white dome is brilliantly illuminated, the delicate green of the statue against the blue-black sky offers a most interesting spot of color.

In the Hall of Representatives, the Speaker's desk, of white marble, is both beautiful and commanding of attention. The committee rooms are elaborately and colorfully decorated.

In the Senate Chamber, the walls have rich decoration in gold arabesques on delicate tints and buff panels. The connecting rooms are also richly decorated, displaying allegorical and symbolic paintings on the ceilings. The corridors, walls, and ceilings of the Senate basement are painted effectively, too.

The exterior of the Library of Congress is of white New Hampshire granite (which, at this writing, is quite gray). The dome, finished in black copper with gilded panels, is topped by a gilded finial representing the torch of science. The inner courts of the building are of Maryland granite and white glazed bricks; the entrance doors, of cast bronze, ornamented with figures in high relief. The vestibule, of white Italian marble, has a gilded ceiling.

The central stair hall of the Library of Congress, unsurpassed

in grandeur by any other entrance hall in the world, is of highly polished Italian marble. The stairway railings and balustrades are elaborately carved. All the ceilings and walls are glowing with color furnished by paintings and mosaic decorations.

On the ceiling panels of the Representatives' reading room are Carl Gutherz's symbolic paintings of the seven primary colors.

The main reading room is decorated with marble walls and pillars in dark reds and yellows.

The newly constructed Library of Congress Annex, behind the old building, is of modern design. The stonework about the West entrance is decorated with conventionalized sculptures in low relief.

The main halls are of two tones of brown marble accented by black marble. Indirect lighting comes from behind frosted glass panels extending on all sides of the ceiling which is of a golden-brown color. Red plush drapes trimmed in gold hang at the windows, and chairs are upholstered in light-green leather.

Simply decorated bronze doors lead to the elevators which carry visitors to the reading rooms on the fifth floor. The large room on this floor containing cabinets of indexed cards has direct lighting from a light-green ceiling. The walls of this room are in two tones of light bluish green accented by darker green marble about the doors which are ornamented by decorative bronze grills overhead. The cabinets are of light green trimmed in silver color as are the writing tables. The floor is of a light brownish composition with black decorative inlays and border.

The Thomas Jefferson Reading Room and other rooms have walls of warm gray fabricated stone decorated with painted murals predominating in blue. The ceilings are of very light green and the floors light brown. The tables and chairs are of dark brown wood. Bronze lamps with bronze standards provide excellent illumination at the tables. Beyond stone pillars on the sides of this room are shelves of reference books. The walls above the books are of a medium green trimmed in silver color.

The whole effect is most pleasing and this building is an excellent example of the best in modern architectural design and decoration.

The White House, the residence of the President of the United

States, is of Virginia freestone. The stone, discolored in the fire of 1814, was thereafter painted white.

The East Room of the White House has the walls and ceilings decorated in white and gold, with window draperies in old gold. Two royal-blue Sèvres vases provide an effective accent for this room.

The Blue Room is the President's reception room. The walls here are covered with rich blue corded silk. The window hangings are of blue, with gold stars in the upper folds. A gold clock, two bronze vases, and two gold-plated candelabra on the mantel contribute their charm to the whole effect.

The Green Room has walls and draperies of green velvet. The wainscoting is white enameled. One side of the room is dominated by a white marble mantel, in front of which stands a screen of Gobelin tapestry in a gold frame. On the mantel are a gilt clock and two gilt vases.

The walls and window draperies of the Red Room are of red velvet. The center of interest here is a cabinet of mahogany and gold, of superb workmanship.

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PART SIX

Relation of Color to Man's Progress

19

GENERAL USES THROUGH THE YEARS

A Chronological Review

The life of man through the ages of his development presents a long panorama of colorful scenes. The need for color is evident as far back as mankind's earliest known attempts to find self-expression, and human beings seem early to have discovered the materials that nature had provided for the gratification of their craving to record in colors the objects of their world and the experiences of their daily existence.

15000 B.C. Evidence has been found in caves of southern France and northern Spain that man in the Reindeer Age used colors to decorate the walls surrounding him. Paintings still exist that were made by these ancient men, representing the animal life that meant so much to them. Their representations of the animals were closely linked with the beliefs that served for religion at that stage of human experience.The range of colors at the artist's disposal was apparently restricted to red, yellow, black, and brown.

4500 B.C. The Egyptians made use of bright colors to decorate the walls of their temples, which were constructed of limestone, sandstone, alabaster, and granite. They added color to their sculpture. The statue of The Princess shows red lips, black hair and eyebrows, and a necklace of red and blue. The statue of Khafre is of stone covered with fine stucco and painted. That of the Sheik el-Beled is of wood covered with fine linen and painted. The walls of the tombs and temples are covered with harmonious murals done in flat, even tones of color.

3000 B.C. The Babylonians, Assyrians, Chaldeans, and Persians built with clay bricks. These they covered with glazed tiles of brilliant colors on both the inside and the outside of their buildings. Their use of color was adapted to their tropical or semitropical environment. Bright colors were in order for their clear skies and

brilliant sunlight. They sought for dazzling brilliance and applied glazed tiles of bright colors to the façades of their buildings, which glistened impressively in the sunlight. Persian interior decorations were designed to be seen in the shade and included rose, flame red, white, and gold on a lustrous blue ground. The Persians occupied a colorful region at a high altitude, where the air was clear, and they took full advantage of the situation. The beautiful glazed tiles on their buildings made a very imposing spectacle, which was visible at considerable distances. These decorations included in their coloring turquoise blue, burnt-out pinks, pale greens, dulled yellows, violets, blues, browns, ivory whites, lilacs, yellows, greens, both pure and in combinations, in designs over white inscriptions and gold arabesques.

1500 B.C. At this time the Egyptians had a high degree of civilization. The walls of their temples inside and out were decorated with low reliefs painted in bright, flat colors. The bright sunlight created deep shadows within and these shaded interiors were adorned in red, blue, green, yellow, white, and gold. Glazed tiles were applied to the ceilings and floors and the mural paintings were supplemented by them. The Egyptians by this time were producing colorful jewelry and glass vases. A typical vase is of dark blue, with a pattern in light blue, yellow, and white. The Temple of Karnak at Thebes, a new structure at this time, was probably the most colorful edifice ever constructed by man. The colors used were all strong; there were no tints. Red, yellow, green, and blue predominated.

About 1500 B.C., the Greeks were enjoying a well-organized civilization. Their temples were decorated with black, brown, white, green, purple, yellow, red, and blue. The color was applied flatly, simply, and purely. It was subordinate to and correlated with the architectural design. White marbles were coated with ivory wax. On the temples, the color was applied chiefly to the upper part of the building. There was little or no coloring in the retaining walls, the peristyle, the column shaft, or its base. The Greeks painted their statues and sculptured reliefs, but not to imitate nature. The use of color in this connection was for purposes of design, and the relative position of the object rather than the subject itself dictated the color used. Thus the hair and beard

of a figure might be painted blue or otherwise. The painting of such figures was a specialized art, and seldom did the sculptor do the painting. Ivory carvings were also painted and gilded.

About 1500 B.C., the Romans were constructing temples of concrete and brick, faced with marble and stucco. Their use of color was largely borrowed from the Greeks.

450 B.C. The Greeks constructed their buildings of marble and decorated them with sculptured reliefs, which they painted. The predominating reds and blues were relieved by touches of green, yellow, black, and gilding. Although the remains of the Parthenon show no traces of color now, it was originally highly colorful. The triglyphs and decorations above and below were in blue. The string courses, metopes, and undercutting of the cornice were in red. Greek players presenting Homer's "Odyssey" were clothed in purple to signify the sea wanderings of Ulysses. When presenting the "Iliad," the players wore scarlet to represent bloody battles. The bacchantes smeared themselves with wine dregs or mulberry juice. Evil spirits were frequently daubed with green (like reptiles).

A.D. 400. During the fourth century of the Christian Era, the ancient Greek town of Byzantium, renamed Constantinople, had been made the capital of the Roman Empire, and Christianity had become the leading religion. Byzantine coloration was much influenced by that of the Persians, Egyptians, and Greeks, from whose buildings many treasures were "borrowed" to beautify the new capital city. The temples, often altered for use as Christian churches, were plain outside, but the interiors were richly decorated with gilding and mosaics.

A.D. 500. Civilizations had been developing all over the world for thousands of years, and by the year 500 many of them showed a high degree of perfection. In India, temples were resplendent with elaborate carvings, brilliant coloring applied with paint, mosaics, and inlays of precious stones. Through the ages, from various associations, color had developed a symbolism in the Far East and was used in accordance with that code. The roof tiles of Chinese royal buildings were of yellow. The roof tiles of private dwellings were of green or blue, according to the rank of the owner. The beams and underside of the projecting roof and the

interiors were elaborately ornamented and decorated with gold, vermilion, lacquer, and inlay. The predominating color effects of the temples were in blue and included tiles of deep cobalt. The pagodas were embellished with beautiful glazed tiles in deep purplish blue, rich green, yellow, red, and turquoise blue. Statues were carved from wood, covered with gesso, and painted.

The exteriors of the Japanese Buddhist temples were usually quite plain, but the interiors were lavishly adorned. The timbers were decorated with vermilion, blue, green, gilding, and lacquer, and the walls with fresco paintings. Mother-of-pearl and silver were worked into the ceilings, rich color and gilding into the walls, and black lacquer inlaid with ivory was used for partitions, etc.

A.D. 650. The Mohammedans, in their mosques, used wood, plaster, and stone, ornamented with ivory, marble, and colored-glass inlay. The walls were decorated with fresco paintings reflecting strong reds, yellows, and blues, supplemented by gold.

A.D. 1000. The Christians were constructing their buildings of brick, stone, and wood. The ornamentation of the interiors, which was not only decorative, but had instructive value, was in the mediums of colorful fresco painting and mosaic. In the Church of Santa Sophia at Constantinople, built about 550, the interior was elaborately adorned and very colorful. Marbles of green, rose, white, and deep red were used. The ceiling was of gold. Colored enamels were applied and ivory carvings were painted and gilded.

In the Americas, civilizations had developed in which bright colors abounded. The Mayans, who occupied lands now known as Yucatan and Guatemala, built of limestone, cement, and concrete. Their structures were painted outside and in with red, yellow, blue, black, purple, and several greens. They painted murals in both wet and dry plaster.

The Aztecs, in what is now Mexico, built of concrete faced with cut limestone. Their structures, like those of the Mayans, were highly colored both inside and out with paint and mosaics.

The Incas, whose influence extended over a large part of South America and was concentrated in what is now Peru, Bolivia, and Chile, used color lavishly. They built for the most part of granite

and, like the peoples of Central America, applied bright colors to all parts of their structures, wove it into their fabrics, and decorated their utensils and equipment with it.

The peoples of Central Africa and Polynesia, the American Indian, and the Eskimo have all found color to be indispensable to their happiness. They have invariably made lavish use of bright, pure colors on edifices, boats, tents, utensils, apparel, etc.

Europe of the Renaissance and After. In most of the smaller buildings of Europe, color has been frequently applied to exteriors. These smaller structures have been constructed mostly of wood and plaster. After the Renaissance, larger buildings of stone bore no other exterior decoration than unpainted carving.

Venetian architecture included façades of various colored marbles, with sculptured ornament enhanced by gold leaf applied on flat grounds of ultramarine blue.

In the Gothic cathedrals of France, stained-glass windows played an important part in the decorative scheme. In addition to these jewel-like windows, the walls, capitals, statues, and ornamental details of the churches were colored and gilded.

In Spain in the sixteenth century, the working of iron became a fine art. The skilled artisans applied or inlaid brass, copper, gold, and other contrasting metals to the iron for decoration. Enamels and gilding were also employed. It was found effective to use red velvet or stained wood as a background for pierced work or for pieces in which the motif was of an open design.

Color in Wallpaper. Wallpaper has for centuries been popular as a decoration of interior walls. The first real wallpapers were developed at Rouen, France, in the sixteenth century. These were "marbled" papers, made by floating off the colors from the surface of water after "combing" them into various marble designs. Other papers were produced in which the outlines of designs were printed by press and colors (distemper and glue) were applied by hand. The first long strips of wallpaper were produced by Fournier in Paris in 1760 by pasting small sheets together before printing. "Flock papers" were developed in 1620. In this case, a mordant, or greasy varnish, was applied to the paper. While it was wet, finely chopped wool or silk of different colors was blown over it. In this way, very satisfactory imitations of brocaded velvet and

tapestry were produced. Madame de Pompadour had flock paper applied on the walls of her dressing room and bathroom.

In the eighteenth century, Reveillon of Paris produced wallpapers of pictorial subjects to represent mural paintings. The long rolls of paper, such as are now used, were not developed until the latter part of the eighteenth century.

Color in the Modern World. In the First World War, color was applied to ships and other objects for the purpose of confusing the enemy. The effect was produced by the arrangement of areas to distort the perspective. In all cases, this camouflage was intended to mislead and trick the eye.

The purpose of camouflage in the Second World War was to conceal. The practices of nature were closely followed and both moving and stationary objects were rendered less visible by the colors applied to them. The undersides of Navy planes were painted light sky blue to blend with the sky. The topsides of the planes were painted to correspond with the general color of the area they would be flying over. This might be dull blue, green, sand, or earth color.

The most generally satisfactory color for guns, tanks, trucks, etc., was found to be olive drab, as it blends best with most surroundings on land. However, for protection at sea, such objects would be colored to blend with the ocean and, in the desert, to blend with sand, etc. Factories and other buildings were painted both to conceal them from the enemy in the air and to confuse him. However, an infrared filter used in an aerial camera detects the difference between green paint and green foliage. Green paint registers almost black, whereas green leaves, containing chlorophyll, appear almost white when this filter is used.

Color was effectively used for attractive value in the world's fairs held at Chicago in 1933–1934 and at New York and San Francisco in 1939–1940.

For many years man has considered the possibility of an art relying solely on colored lights for its expression. Aristotle suggested the possibility and a Frenchman wrote about it in the eighteenth century, but it was not until the advent of electric lights that the idea gained much momentum. In recent years, Thomas Wilfred (born in Denmark in 1889) has developed such

an art and brought it to a high degree of perfection. He produced a "color organ" in 1919 and regularly entertained a large and enthusiastic audience with his silent moving compositions in color, giving concerts in Europe in 1925. The effects are produced by the manipulation of beams of electric light, the lights, colors, and movements being controlled by the clavilux, an instrument invented by Mr. Wilfred. It is believed that in time this instrument will be made practical for home use or for any place where electricity is available. This medium of expression is very effective in influencing the mood and mental attitude of the observer. It is independent of languages, nationalities, education, and temperament, and of the degree of civilization. It is as universal as the sunset. One of Mr. Wilfred's dreams is the establishment of many "halls of silence," everywhere throughout the world. In these halls, insulated from the noises of the street, mobile color will be automatically and continuously thrown on the walls, the ceiling, or a screen within. Such places are to be open for the public to use as it can use a church, to obtain rest, peace, quiet, inspiration, and spiritual strength. Such simple fountains of strength might be established in connection with churches, factories, office buildings, stores, etc., or in any public or private building in any part of the world where humanity congregates.

Many composers of music have claimed that certain musical sounds are related to definite color sensations and have composed music while keeping this in mind.

Motion-picture films have been produced and exhibited in which changing abstract forms and color provide the only entertainment. Others have been synchronized with music. The first abstract film—"Diagonal-Symphonie," by Viking Eggeling—was produced in Berlin, Germany, in 1919.

Later productions include the following:

"Prelude" and "Rhythmus 21," Hans Richter, Germany.
"Opus 1, 2 and 3," Walter Ruttman, Germany.
"Color Box," 1935, Len Lye, Australia.
"Rainbow Dance," 1936, Len Lye, Australia.
"Trade Tattoo," 1937, Len Lye, Australia.
"Swinging the Lambeth Walk," Len Lye, Australia.

Some such films produced in this country are

"Escape," Mary Ellen Bute and Theodore Nemeth.
"Rhythm in Light," Mary Ellen Bute and Theodore Nemeth.
"Parabola," Rutherford Boyd.
"Fantasmagoria," Douglas Crockwell.

In 1925, Maude Adams designed "Color Dynamics," which was produced by the Eastman Kodak Company.

For educational use in illustrating problems of higher mathematics in animated form, B. G. D. Salt and Robert Fairthorne produced "X + X = A Syn N +"—a film that is available in the film library of the Museum of Modern Art, New York City.

Other films are available at the Museum of Modern Art, Expanding Cinema Productions, Commonwealth Pictures Corporation, and Teaching Film Custodians, all of New York City.

Chromotherapy

The treatment of human ills by means of color has been practiced sporadically since ancient times. There is evidence that it was employed in this connection by the Persians, the Greeks, and the Arabians. Avicenna wrote numerous treatises early in the eleventh century describing the connection between color, emotion, and health. Paracelsus was an alchemist and color healer in Europe in the fifteenth century.

The power and influence of color have always been available, but there is much to be learned about its application for the treatment of disease. Several volumes and articles have been written on the subject of chromotherapy and some progress has been made, but there is as yet no general use of color that can replace medicine and surgery. Doctors Seth Pancoast and Edwin D. Babbitt were pioneers in this field, publishing "Blue and Red Light," in 1877, and "The Principles of Light and Color," in 1878. These books were the accepted guides of color practitioners for several years.

Dr. Edward Podolsky in "The Doctor Prescribes Color," states, "There is as much actual healing in colors as there is in drugs, heat, massage and other physiotherapeutic methods. And these medicinal effects are as real and measurable as any obtained through other means."

Dr. Noel Scott, Surgical Assistant at the Royal Waterloo Hospital in England, observed "the remarkable effects colors exert in a variety of diseases."

Dr. K. W. Baldwin, former Senior Surgeon of the Women's Hospital of Philadelphia, has said:

> If the body is sick, it should be restored with the least possible effort. There is no more accurate or easier way than by giving the color representing the lacking energy elements, and the body will, through its radioactive forces, appropriate them and so restore the normal balance. Color is the simplest and most accurate therapeutic measure yet developed.
>
> For about six years, I have given close attention to the action of colors in restoring the body functions, and I am perfectly honest in saying that after nearly 37 years of active hospital and private practice in medicine and surgery, I can produce quicker and more accurate results with colors than with any or all other methods combined and with less strain on the patient. In many cases, the functions have been restored after the classical remedies have failed.
>
> Of course, surgery is necessary in some cases, but results will be quicker and better, if color is used before and after operation. Bruises, sprains, and trauma of all sorts respond to color as to no other treatment. Septic conditions yield, regardless of the specific organism. Cardiac lesions, asthma, hay fever, pneumonia, inflammatory conditions of the eyes, corneal ulcers, glaucoma and cataracts are relieved by the treatment.[1]

Corinne Dunklee Heline, in "Healing and Regeneration through Color," states:

> The New Age preventative against epidemics which will replace the present barbaric custom of vaccination will be the scientific use of color. Each ductless gland, for example, possesses what we may call a "color power," which is the energy radiation visible to the extended etheric vision. This color power when properly focused will overcome and eradicate certain diseases caused by a lack of the stimulus native to that color. The color radiation of the pineal gland is blue-lavender; the pituitary, blue-yellow; the thyroid, green-gold; the solar plexus, orange; the thymus, golden pink; and the adrenals, bright purplish red.[2]

[1] Baldwin, K. W. "The Therapeutical Value of Light and Color," *Atlantic Medical Journal*, Vol. 130, p. 432, as quoted by Ernest J. Stevens, in "True Chromotherapy," The Rainbow Publishers, San Francisco, Calif., 1938.

[2] Heline, Corinne Dunklee, "Healing and Regeneration through Color," J. F. Rowny Press, Santa Barbara, Calif., 1944.

Color healing is said to be able to effect physical, mental, and spiritual adjustments. Color's vibrations received through the eye affect the emotions, which in turn affect the functioning of various organs. The effect of color's vibrations on cells and glands depends on their energy radiation and is independent of vision.

That mental attitude is an important element of recovery in any illness and that color influences mental attitude has been known for centuries. Its use in this connection is being widely practiced today.

Symbolism

From long-continued association of color with events and ideas, a symbolism or language of color has developed. Each day symbolizes man's life, from the white of dawn (birth) to the black of night (death). Green and the lighter tints of colors are associated with springtime and represent cheer, hope, and freshness. With the early summer come yellows and stronger tints and with late summer, reds, purples, and blues, all of which is a period of life on the road to maturity. Autumn is the period of maturity, ripeness, and strength. At that time nature's riot of color includes yellows, browns, purples, and greens. Winter is the time of old age and death. Its cold sadness or sullenness is accompanied by white, black, and grays.

All the ancient civilizations developed elaborate symbolizations of color. To them, indeed, the symbolic use of color was more important than its artistic use.

The Chinese and Siamese players today, as they have for centuries, paint their faces red, yellow, blue, green, or white, to dramatize different characteristics.

God was supposed to have given Moses five mystic colors—red, blue, purple, white, and gold—the usage of which was prescribed by divine command (Sarum ritual). The Greek church used only two colors, of which red was for Lent. The Roman church used red, green, violet, black, and white. In the church red has been the usual Sunday color, as well as the color of penitence on Ash Wednesday, Good Friday, Easter Even, Whitsun Even, etc. White has become symbolic of Eastertide; yellow, of confessional feasts; and brown or gray with violet, of penitence. Violet or

amethyst has been associated in the church with passion and suffering as related to love and truth. The trinity of color was red (divine love), blue (truth and constancy), yellow or gold (divine glory).

The use of color through the ages has been characteristic of the nature of the people and the social, political, and economic conditions under which they lived, and has reflected their energy, power, wealth, and cultural development.

The significance of color according to its traditional use and associations is herewith outlined.

Red (blood). As used by the church in festivals of martyred saints and the Holy Cross, red signifies divine love, charity, and martyrdom for faith. Adam means red—the emblem of human life. Furthermore, red stands for health (India), tragedy, anger (seeing red), shame (scarlet woman), courage, battle, bravery, strength, passion, love, guilt (red-handed). By association with blood and fire, red symbolizes heat, war, cruelty, hate, power, destruction (Japan), danger, anarchy, revolution. This color is used by the Chinese in connection with marriage. In England, it is the color of the royal family. Red stone was always used for the calumet of the American Indian. Pink is associated with beauty, tenderness, and femininity.

Orange (autumn). Rich harvests and plenty, abundance and completeness of life are symbolized by orange; and because it is the color of flame, it signifies, also, light and heat.

Yellow (fire and sunlight). Warmth, light, sun, marriage and fruitfulness (India), gaudiness, gaiety, luster, enlivenment, and glory (divine) are all included in the symbolic use of yellow. It is the royal color of the Ch'ing dynasty of China and the color sacred to Brahma, Confucius, and Buddha. From the color of gold are derived the further meanings, glory, power, wealth, and greed; from the yellow robes of Athena, wisdom; from the treachery of Judas—portrayed by early artists as wearing a dull-yellow robe—deceit, cowardice, inconstancy. In the tenth century, in France, the doors of the houses of criminals were painted yellow. Saffron robes were used by confessors in the church. From association with cowardice, we use the expressions, "he is yellow" and "he shows a yellow streak." To indicate indecency, we speak of "yellow

journalism." From association with sickness and disease, we use a yellow flag for quarantine.

Brown (rocks, trees, earth, etc.). Strength, solidity, vigor, maturity, and concentration (brown study) are the characteristics symbolized by brown. It is, besides, a color of penitence in the Church.

Green (grass, foliage of springtime, etc.). Freshness, youth, life, adolescence, growth, vigor, hope, cheerfulness, plenty, immortality (Egypt), faith, contemplation, memory, baptism (pale green), immaturity, and inexperience (greenhorn), all can be represented by green. It is used by the Church from Trinity to Advent Sunday. In some instances in early history, green was considered a sacred color (Druids in England). Green is worn on the turban of a Mohammedan who has made the pilgrimage to Mecca. It is the color of Ireland (shamrock), the color of victory (palm branch), the color of peace (olive branch), the color of Neptune (green sea). This is, also, the royal color of the Ming dynasty. Green is sometimes associated with jealousy (green-eyed monster).

Blue (sky). Serenity (bluebird of happiness), loyalty (true blue), courage, fidelity, constancy, sincerity, piety, love of good works, hope, heaven, dignity, truth, generosity, divinity, peace, Christian prudence, sedateness, intelligence, aristocracy (blue blood), melancholy (feeling blue, blues singer). It is the sign of tribulation to the Cherokee Indian and the color of mourning in Mexico.

Purple and Violet. Probably because of its costliness, in early history purple was used only by royalty and by the Church and, through this association, came to symbolize royalty or the state. It was used by the Roman emperors (personification of Jupiter). It signifies dignity of justice, secrets, mysteries, heroic virtue. In the Church, purple is the color of penitence, in connection with the saints, Advent, Lent, etc.

White (snow, etc.). White has long been used in the Church in connection with festivals of angels, the Virgin Mary, Christ, the saints, and also with matrimonial ceremonies. It symbolizes purity, simplicity, the untouched, the uncontaminated, the unadulterated, truth, innocence, chastity, light, modesty, liveliness (without gaiety). It is used by the Chinese for mourning. Purity

(lily), peace (dove), outward purity only (whitewash), surrender and humility (white flag), timidity (white feather), untried manhood (white shield), the feminine, the delicate (white skin) are symbolized by white.

Black (absence of light). Black is associated with darkness, fear, gloom, terror, dread, death, mourning, woe, wickedness, crime, evil, and horror, as is indicated in such expressions as "black sheep," "black tidings," "black soul," "black looks." "Black art" is a term applied to witchcraft, secret wisdom, diabolical power; "black flag" to piracy and lawlessness. In the Church black is a symbol associated with Good Friday, funerals, and memorial services. Black and white in combination signify humility, melancholy, resolution, solemnity, secrecy, prudence.

Gray (having attributes of black and white). Tribulation, penance, humility, sadness, age, matured judgment, dreariness, quietude, solitude, fear, death, sobriety, and depression are all denoted at times by gray.

Various colors have become associated with various activities and interests of man. The red and white stripes of the barber's pole are symbolic of blood and bandages, from the time when the barber served also as a surgeon. Three gold balls are the pawnbroker's sign. Red lights indicated the establishments of "scarlet women." Red is universally used by fire departments. Green lights are used in this country to mark some police headquarters. The Red Cross symbolizes a broad humanitarian service. Blue is the color most widely used for uniforms. Dairy wagons are usually white. Undertakers and religious workers wear black. Doctors and nurses wear white. The black shirt and the brown shirt have symbolized certain political groups. The white collar is a symbol of the clerk in business. Gaudy color combinations are associated with the circus and with sports. In some places, broad black and white stripes and other such arrangements are the mark of the prisoner.

"True blue" referred originally to a stanch Presbyterian, because the Covenanters have adopted blue for their color, as opposed to red, the royal color. From the blue ribbon worn by the Knights of the Garter comes the use of the phrase "blue ribbon" as the highest mark of distinction that can be worn (Encyclopaedia Britannica).

Since 1893, the universities and colleges of America have used the following hues on gown, braid, or tassel to identify major faculties: scarlet, theology; blue, philosophy; white, arts and letters; green, medicine; purple, law; golden yellow, science; orange, engineering; pink, music.

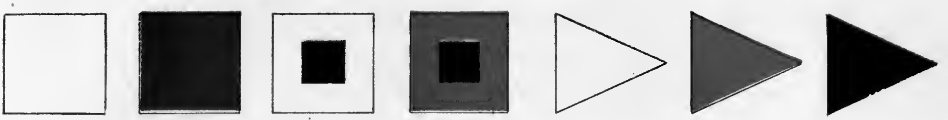
Iris, the goddess of the rainbow in Greek mythology and the messenger of Zeus and Hera in Homer's "Iliad," was the personification of the rainbow and was portrayed as a young virgin clothed in bright colors, wearing golden wings, and carrying a staff and a vase. In Norse mythology, the rainbow was the bridge between Midgard (home of man) and Asgard (home of the gods).

In his painting in the Library of Congress at Washington, Carl Gutherz has used the following color symbols: violet for the state, indigo for science, blue for truth, green for research, yellow for creation, orange for progress, and red for poetry.

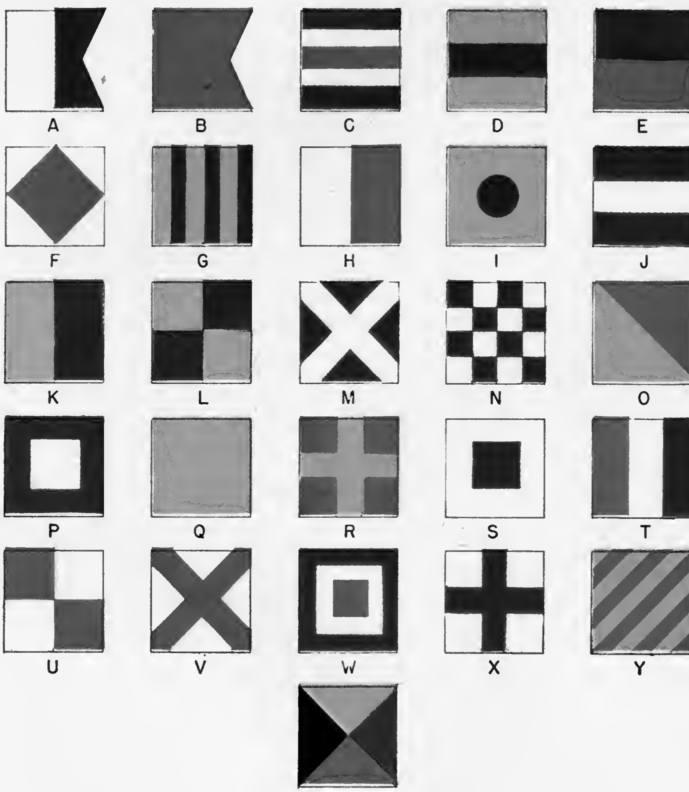
The colors and patterns of signal flags are intended to convey certain information. The accompanying chart shows details of weather signal flags and code signal flags. The first are used to report general weather conditions and the latter to convey a message when no other means are available.

The origin of the colors used on national flags is subject to dispute in some instances. The oldest flag in existence is said to be the Dannebrog of Denmark. This is a red swallow-tail ensign, with a vertical-horizontal white cross and is said to date from about the year 1219. Pieces of cloth were used before that by various groups of people to signify their union, but none to the extent of being considered a national flag. A group of Persians, in 800 B.C., used the apron of a blacksmith as their standard in a revolt against despotism. The national flag of Switzerland, a white cross on a red ground, antedates the year 1300.

Egyptians and Romans carried standards in battle. Through the ages, families and small groups displayed their own individual flags, banners, pennants, streamers, standards, etc. These insignia, in the Middle Ages, were designed and executed in accordance with the laws of heraldry. The design was usually related to a family coat of arms. This shield, standard, or other device, was known as a "blazon," and the art of designing was called "blazonry." In blazonry, yellow represented gold, and white represented silver.



⊗ *Temperature signal above weather flag = warmer; below = colder*



According to the laws of heraldry, color was not placed on color, or metal on metal. Most national flags have recognized these laws, but many have violated them. Among the violators of these ancient laws are Portugal, China, Estonia, Lithuania, Bulgaria, Venezuela, and Czechoslovakia.

The red, black, and yellow of the Belgian flag are said to have been the colors of the Duchy of Brabant (1831). The colors of the flag of Holland were originally orange, white, and blue—the colors of the House of Orange. However, at some time before 1643 red was substituted for the orange. The blue and white of the flag of Greece were the colors of the House of Bavaria (Prince Otho, 1832). The white star and crescent on a red field of the flag of Turkey is the symbol of Diana, patroness of Byzantium. A crescent moon betrayed the enemies in the siege of Constantinople. The present flag of France, introduced during the French Revolution, has a doubtful origin. Some say that it comes from the colors of the City of Paris (red, white, and blue). It may have developed from the blue of the *chape de St. Martin*, the red of the oriflamme (ancient banner of St. Dennis, which was carried before the early French kings), and from the white flag of the Bourbons.

The colors of the American flag may have been influenced by the Union Jack or by George Washington's coat of arms. The latter was a white shield with two horizontal red bars. As we know, the 13 stripes represent the 13 original colonies and each star represents a state. The union jack, the national flag of the British Empire, is a combination of the crosses of Saint George, Saint Andrew, and Saint Patrick. Saint George, the patron saint of England, had a banner of silver with a cross gules (vertical-horizontal red cross); Saint Andrew, the patron saint of Scotland, had a banner of azure with saltire silver (diagonal white cross); Saint Patrick the patron saint of Ireland, had a banner of silver with saltire gules (diagonal red cross). The flags of Australia, Canada, and New Zealand incorporate the union jack with other features.

A blood-red flag has come to symbolize mutiny and revolution; a black flag, piracy. The latter is now flown after an execution. A yellow flag is recognized internationally as a signal of infectious illness or quarantine. A white flag is a universal signal of surrender

or of truce. The national ensign displayed upside down or knotted in the middle is a signal of distress.

The traditional symbolism of color persists to some extent in our use of color today, but as color is being put to work, new symbols are being developed.

Acknowledgment is given to the following sources of information. See also Part Seven.

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20

SPECIAL USES OF COLORS TODAY

In Many Fields

To quote from Dr. Deane B. Judd of the National Bureau of Standards, "Color permeates the life of nearly every member of modern civilization. Printed forms, colored signals, tickets, billboards, and warning signs are everywhere."

Among other things to which color has been more or less intelligently applied are streets, sidewalks, office buildings, delivery trucks, pleasure cars, packages and containers of all kinds, fountain pens, typewriters, cameras, kitchenware, alarm clocks, toilet paper, fish foods, tombstones, bathtubs, telephones, stoves, trains, buses, airplanes, eyeglass frames, sugar, paper napkins, table linen, bed sheets, rubbers, coal, gasoline—and almost everything else, in fact.

The following information has been received through the courtesy of Thomas J. Dee & Company, Chicago, Ill.:

> In the Southern states, dentists working principally with colored patients order a special red-colored gold, especially for use in the front of the mouth. This gold is very similar in color to United States gold coins. It is very little used in dentistry outside of this area.
>
> There is a certain color preference in various parts of the United States for yellow gold, greenish gold, or even gray gold for use in dentistry, and many dentists insist that all the gold that they use, even though it has various physical properties, must match in color.
>
> In the jewelry-gold field the fashion changes from white gold to green gold to red gold, and it is often hard to determine the cause of this change. During and after the last war, white gold was demanded, probably because it resembled platinum, and platinum was very expensive during the last war. During and following this war, apparently the red golds or pink golds seem to be in demand.

Colored lights are used everywhere to beautify, attract attention, and influence moods and behavior. Stores, factories, hos-

pitals, homes, theaters, ballrooms, lecture halls, interiors and exteriors of every description, and even nature herself are bathed in colored lights by man for one reason or another. The majestic Niagara Falls, which for ages has fascinated men by sunlight and moonlight, has been illuminated artificially at night, with remarkable effect. Great batteries of changing colored lights have been directed on the sheets of falling water and rising mists, producing a soul-inspiring spectacle. It attracts attention because it is artificial and unusual, but it is positive evidence of the fascination of color.

The customers of a cafeteria where walls were painted light blue complained of being cold. After the baseboards had been painted orange and orange slips had been put on the chairs, there were no more complaints, although the temperature had not been varied. While Blackfriars Bridge in London was painted black, suicides on it were frequent; but after it had been painted bright green, the suicides decreased by one-third.

Since white is the color of mourning in China and other parts of the Orient, the natives refused to patronize gas stations that were painted white. It is said that cars are not painted green in England because the color is considered unlucky in that connection. Many nitroglycerine trucks are painted bright yellow, because that color has proved to be more compelling of attention than red.

Color is making strides in photography of all kinds and may some day eliminate the black and white motion pictures. Still compositions in black and white will always have a certain amount of appeal, but when life and action are portrayed, they lack a very vital element without color. If the goal of motion pictures is to dramatize and present a realistic illusion of life, the ultimate product will incorporate all the elements of sight, as well as of sound. Sight includes not only color but solidity or relief. Solidity can and may be effected by applying the principles of the stereoscope. The color of animated cartoons has contributed enormously to their popularity. Educational films are vastly more instructive with color than without. Historical dramas, musical comedies, operas, or any other spectacles are only half as forceful without color.

Phosphorescent paint is applied to watch and clock dials, poison labels, keyholes, doll's eyes, etc., to make them luminous

in the dark. A particle of radium as small as a pinhead will make zinc sulphate shine on hundreds of thousands of watches. If these glowing parts are examined by a powerful microscope, tiny explosions of radium atoms are seen. This bombardment of zinc by radium occurs at a frequency of about 200,000 times per second and continues for about two years. Fluorescence is observed through the use of X rays or ultraviolet rays. Rooms and signs are painted with fluorescent pigments to attract attention by their novel appearance. Some advertising posters are so treated that they appear blank in parts under ordinary light, but take on various colors when exposed to ultraviolet light. Others are treated to glow not only in the dark but in sunlight as well.

Ultraviolet light and fluorescent pigments are used on the stage with dramatic effect. Ultraviolet light, although in itself invisible to man, can make some other invisible things visible to him. By means of this power, it is useful in detecting foreign matter in foods, forgeries and alterations of documents, adulteration of drugs and chemicals, and in differentiating cotton from silk, old paintings from recent copies, etc. A food containing the vitamin lactoflavin glows with an intense yellow light when exposed to ultraviolet light in a dark room. These rays activate ergosterol to become vitamin D and increase the percentage of inorganic phosphorus and calcium in the blood. They can assist in building bone tissue and help to increase one's resistance to disease, but they can also burn the skin, damage the eyes, and kill living substance. Various waves of invisible light are useful in the treatment of diseased organs; in the killing of insects in nuts, furs, tobacco, bags of wheat, etc.; and in the pasteurization of milk.

Color is applied to men's and women's faces on the stage, in the motion pictures, and in ordinary life. Women have been coloring their faces, hair, and nails for generations in all parts of the world; but the practice was never so universal before as it has become now. Some men of all classes continue to have battleships, dragons, etc., tattooed on their bodies; but it is not likely that they will ever adopt face painting in a big way. Some have been known to stain themselves to simulate a healthy tan, when they had been unable to acquire one in a natural way. Make-up as a medium of dramatic expression is used for attraction and emphasis. Its use

should be influenced by the character and the environment of the individual. A make-up that might be effective on the stage might be entirely ridiculous on the screen or the street. Actors and models who are being photographed in natural colors usually use only a natural make-up. Actors on the stage must overcome the distance between the stage and the gallery and thus use strong, but natural, colors.

On the other hand, colors are used for make-up in the black and white motion pictures in a different way. The purpose is still to dramatize the characterization, but much consideration is given to photography. With an ordinary film, red, orange, and brown photograph almost like black and blue; pink, yellow, and mauve photograph almost like white. Thus beautiful pink cheeks appear dirty gray and a spot of rouge would appear to make a hole in the face. Gold teeth may show up as black spots and freckles appear darker than they are. The ordinary screen make-up frequently has a purplish cast. Protruding eyes may be corrected by tinting upper eyelids green. A bit of red under the nose makes an optical shadow. A double chin can be made less noticeable by putting it in an apparent shadow with a tint of red. More sensitive films permit a more natural make-up, because they reproduce light and shade more naturally. White actors using a ruddy make-up on the stage can be made to appear as Negroes by throwing a green-blue light on them.

It has been observed that many forms of life make use of camouflage for purposes of concealment. On occasion man also has employed color for scientific deception. Its effectiveness results from noninterference with the natural or normal aspect of the locality. Khaki and light-gray uniforms blend most readily with the usual surroundings. A ship painted light gray is less visible than one painted black. "Dazzle painting" has been applied to ships and other structures to distort their normal appearance and confuse the observer as to their courses, etc. This effect is produced by the juxtaposition of violently contrasting colors, combined with the laws of perspective. Such an effect can be nullified by the observer's looking through an appropriate color screen.

Different systems of wires that come together, as in a telephone switchboard, are made distinguishable by giving them different

colors. In anatomical models, different organs, nerve systems, etc., can be distinguished more easily if they are colored differently. In any situation in which the uninitiated would normally be confused, as in a complicated subway terminal, lines and lights of different colors help to show the way. Colors are used for communication at short range, as with signal flags on board ships. In all sorts of educational work in the classroom or on the lecture platform, color is effectively employed to get interest and attention, to help convey ideas, to make presentations clearer and more vivid, and to aid the memory.

Color is used in schoolrooms to foster interest and activity by creating an atmosphere that is friendly, lively, cheerful, and mildly stimulating. Amber chalk is finding favor in schools, because it is easier for the eyes than white chalk on blackboards. It is easy to see and the color factor lends interest. Various other colored chalks are used to emphasize or correlate ideas and aid the memory. Black chalk on yellow "blackboards" has proved more satisfactory in some schools than the usual black and white combination.

Black and white are useful in controlling heat. Black absorbs heat and raises the temperature of that which it covers. White reflects heat and insulates the body it covers from external heat and spreads the heat around.

The American Liquid Gas Corporation, of Los Angeles, Calif., offers an industrial example in this connection.

We might suggest one specific use that others may have overlooked and that is the effect of color in connection with the storing of certain articles. For instance, in handling petroleum products that are subject to increasing vapor pressures with increased heat in warm weather, light paints, such as aluminum, white, etc., are used to paint the outside of storage containers and metal surfaces exposed to the light, as the light colors deflect the heat rays and keep the contents of the containers at a lower temperature. Of course, this is true not only in use with petroleum products but for storage of water or any other products where a lower temperature is desired.

The reverse situation is encountered in cooler climates, where dark colors, such as black, dark green, etc., are used to absorb the heat rays, increasing the temperatures within the container.

Piccard experimented with black and white. When he painted the gondola of his balloon black, the temperature inside rose to 100° while it was 75° below zero outside. When he painted it white, the temperature in the gondola was near freezing. If one painted a room black in the tropics, it would be cooler while the sun was shining than a room painted white under the same illumination. The white-walled room would, however, be cooler after the sun went down. The black walls would absorb the heat and tend to retain it. A room can be given the appearance of being smaller by having the walls painted dark red, or the appearance of being larger by having the walls painted light blue. A large, flat area of red appears to be closer than it really is, while the blue area appears farther away.

Concrete roads of dull orange have reduced the glare of sunlight and headlights by 40 per cent as compared with the ordinary light-gray roads. Such colored roads can also indicate routes. Claret-colored cloth on billiard tables leaves less afterimage than does the usual green cloth. Colored sails have been used on yachts for identification. Boat bottoms painted light pink, yellow, green, or white gather fewer barnacles over a period of time than do bottoms painted a dark color.

A transit company in the Middle West uses different colors on its cars to indicate their destinations. A subway system in the East uses different colors in its stations, to help the passengers recognize their destinations. A railroad in the South colors the caps of oil cups on its equipment and the grease and oil containers, to help the lubricator apply the right lubricant in the right place.

William Jerome Daly, Secretary of the Board of Transportation of the City of New York, favors us with the following information:

> The use of color in subway stations for identification purposes was first instituted in 1928 in the construction of the IND division of our transit system. The stations were divided into groups consisting of an express station and the following local stations up to the next express stop. All the stations in each of these groups were decorated with the same basic color. There are five basic colors, being lavender, blue, green, yellow, and red, which are used in this same sequence, starting from the

centrally located Chambers Street—Hudson Terminal Station, and extending in both directions. This arrangement permits commuters, familiar with the system, to make quick check on their locations from trains.

Thus the Chambers Street station is distinguished by lavender; Canal Street, blue; Washington Square, green; 14th Street, yellow; Pennsylvania Station, red; 42nd Street and 8th Avenue station, lavender: etc.

Every intelligent use of color has paid dividends. It is reported that in one year color alone was responsible for an increase of $26,000,000 in hardware sales. On the other hand, a British brewer introduced a bright green beer. It was bottled and distributed to various parts of the world and advertised extensively. It tasted exactly like any other good beer and the coloring ingredient was perfectly harmless, but it did not find favor with beer drinkers. Color simply as a novelty has little lasting value. Like anything else, to gain lasting popularity it must be useful, serve a real purpose, and fill a real need.

In her article "Bright New World"[1] Muriel R. Rattner describes some novel uses of color. She states that A. R. Zeno, of Puerto Rico, has developed a process by which baby chicks emerge from their shells colored purple, red, blue, pink, or green. "Two hours before the chick is due to hatch, a harmless powdered vegetable dye is injected with a thick needle into one end of the egg. The small hole is stopped up afterward with wax. A couple of hours later, the egg breaks and out steps a baby chick which is normal in every respect save that its own mother wouldn't recognize it." The coloring lasts two to four months, or until the chick moults. The dyes take only on white feathers.

Miss Rattner also describes the work of Dalio Ivani, who grows daisies near San Francisco. He feeds a vegetable dye to white daisies after they are cut, which causes them to take on the color of the dye. The blue dye is deposited in the petals of the flower in about 45 minutes. The yellow dye requires about 24 hours.

Even as a novelty, color is more effective if it is used with reason. White flowers and white bread can be colored green for St. Patrick's

[1] Rattner, Muriel R., "Bright New World," *This Week*, Oct. 27, 1946, p. 8.

Day; a red, white, and blue cake is appropriate for Independence Day, and eggs are colored at Easter time; but artificially colored flowers, eggs, and bread have no lasting appeal. To be of lasting value, color must make a definite contribution to efficiency, health, happiness, knowledge, productivity, or wealth. For instance, painting the bottom step of the cellar stairs or the floor at the base of the stairs white or some contrasting and easily visible color is a good preventive for accidents.

Every magazine on the newsstand employs color on its cover to attract attention. Some newspapers run a line of color in a margin to indicate the final or some other edition. The old *Police Gazette*, a fixture in nearly every barber shop in the country for years, was recognized by its pink paper throughout. The current publication has added color printing to its make-up.

Steel is tempered at certain temperatures according to its various qualities, and the correct temperature is estimated by the color of the steel. When the color indicates that the steel has been heated to the proper temperature, it is "quenched" in water or oil to impart hardness. Tempering colors, which range from bright yellow down to gray, include pure yellow, dark yellow, brown-yellow, red-brown, purple-red, violet, cornflower blue, and pale blue. Bright yellow gives the hardest temper suitable for steel-engraving tools and certain metal-cutting tools. Colors at the other end of the range are suitable for wood saws, springs, etc. The color is judged either by the eye alone or with the aid of an optical pyrometer.

The alloy, chrome cobalt, changes color with different degrees of temperature. After it completes one scale of colors it begins again and repeats the colors through a higher range of temperatures. It reflects the following colors at the degrees of temperature indicated: buff at 500°C, brown at 525°, red at 550°, reddish brown at 575°, dark blue at 600°, medium blue at 625°, blue at 650°, turquoise at 675°, slate at 700°, yellow at 725°, violet at 775°, green at 800°, dark green at 900°.[1]

Robert F. Martin, Executive Secretary of the Vitrified China Association, Inc., advises:

[1] "Metal Reveals Turbine Heat," *Popular Science Monthly*, August, 1946, p. 104.

Aside from the usual use of colors for guide and danger indications in our plants, the use of combination color or "daylight" lighting in our decorating shops, and so forth, which are common to all industry, we have a very special kind of use for colors in keeping track of batches of different shapes and bodies in process. We take advantage of the fact that vegetable base dyes "fire out" and disappear in firing in the kiln, while mineral base colors endure. The decoration is therefore applied in mineral colors, while vegetable colors are used for identification marks on the ware in process. Visitors are sometimes horrified to see stacks of beautiful china "ruined" by colored markings of all sorts smeared on it and absorbed into the clay body so deeply that it obviously can't be washed or rubbed off!

Color is of course of paramount importance to us in the decorations on our ware. More and more attention is being paid by hotels and institutions, as well as by housewives, to seeing that their china decoration colors fit in with their general decorative schemes.

The Forest Service of the U.S. Department of Agriculture, in their motion-picture program, have turned entirely away from black and white and, for training as well as for informational and educational films, are now shooting everything in color. They use color also in their posters on fire prevention and on forest and range management.

The Corps of Engineers of the U.S. Army makes use of color in two general fields: (1) visual aids; (2) camouflage. All the technical services use color to some extent in visual aids, for the purpose of accentuating and defining. Camouflage, on the other hand, employs color to blend and confuse.

Color has been found useful in hospitals and sanitariums. As has been noted before, a blue-green light helps the surgeon in the operating room, because it is easy for the eyes and complements blood. Red has been found to lift insane patients out of their melancholy. Blue is effective in neurotic cases. Gaudy designs in contrasting colors help to mend shattered nerves.

In a letter to the writer, Joseph W. Sanford, Warden of the U.S. Penitentiary, Atlanta, Ga., states:

The cell blocks and other parts of the institution are painted in cool greens, warm ivory, beige, and light buffs. They contribute to restful

living. Gone are the battleship grays of the past. Our kitchens also are resplendent in buffs, greens, and chromium. Color also is added by the many beautiful pictures and prints throughout the institution.

Since we also use color in our hospital and especially recognize its importance in the psychiatric wards, I enclose a memorandum prepared by the Chief Medical Officer and the Psychiatrist.

Part of that memorandum was included in another chapter of this book. The remainder is quoted here.

Color has been used in this hospital over an extended period of time in treating certain types of nervousness. We have had rooms painted green, red, and blue in their entirety, including ceiling, floor, walls and fixtures. Green rooms have been found useful in treating patients with tendencies toward depression and despondency. Blue has been found valuable in treating patients who are in mild states of excitement, hyperactive and anxious. Red has been found of value in treating apathetic patients and patients with a tendency toward hysterical dissociated states.

George Hess, Senior Surgeon (R), Chief Medical Officer.

Harry R. Lipton, M.D., Psychiatrist.

We thank B. S. D'Ooge of the Athol Manufacturing Company, New York, for the following interesting information, quoted from his letter.

1. Children's textbooks, even though in sets, should never be in the same color, for when each succeeding book is in a different cheerful, bright color, the child takes additional interest in progressing.

2. The use of a different color for each volume of a children's encyclopedia, well known to the general public, increased the sales over the old type of binding in one color to a very marked degree.

3. On the basis of data collected from libraries and teachers in the grade schools, children were quicker to pick up books bound in blue or green than they were books bound in red or yellow, contrary to the general belief.

4. The New York Public Library for the Blind has volunteer typists who copy books, using Braille typewriters so that the blind may read up-to-date literature. Because these books were to be read by blind people they had generally been bound in some drab, uninteresting color of buckram.

As an experiment, these books have been bound in very bright, attrac-

tive colors of buckram and the volunteers who have been typing have increased the number of books which they have typed and additional volunteers have been added, so that now they turn out many more books for circulation among the blind.

5. Along this same line, some ten years ago Miss Rose Murray, in charge of circulation at the New York Public Library, specified bright colors for library rebindings, instead of the drab colors one is accustomed to see in libraries, and circulation in the library system of the city picked up to such an extent that she is positive that these new, bright colors had a great deal to do with it.

Television in full color is now accomplished. Its performance depends in part on phosphors. In connection with television and fluorescent lighting, the following is quoted from "The Fascinating Story of Cold Light," by George Albee.[1]

A phosphor is a substance which glows with a light of its own when it is bombarded—sometimes for quite a while after bombardment—by a source of radiant energy. Shining while the outside source of energy is exciting it, it is fluorescent. Shining afterward, it is said to be phosphorescent.

The television receiver you will soon have in your home will depend a great deal upon these materials known as "phosphors." (Postwar sets, with movie-size screens, will also owe much to Du Pont's Lucite plastic, but that is another story.) The image on a television screen is penciled there by a tiny, powerful beam from an electron gun. Sweeping back and forth, the beam draws a line of light and shadow—only a single line at a time, but it is traveling so fast from left to right, moving at the rate of 3,600 miles an hour, that the whole picture is created on the screen in the flash of an eye. It is here that phosphors enter into the picture—quite literally, for the inner surface of the big, funnel-shaped television receiving tube is frosted with phosphor crystals. It is the phosphor crystals that glow and fade, many times each second, as they are needled by the electron beam. The picture is scratched on the face of the tube, you might say, in fluorescent light.

It has been known for almost a century that many substances were fluorescent. A solution of quinine sulphate, for instance, absorbs violet rays and sends them out again as a bright blue beam. An alcohol solu-

[1] Albee, George, "The Fascinating Story of Cold Light," *The Du Pont Magazine*, Vol. 39, pp. 6–8, October, 1945.

tion of chlorophyll—the stuff that makes green leaves green—fluoresces a brilliant red.

Scientists now put these phosphors, which have been such a fascinating subject of speculation, to work—as in television. The story is an interesting one for in the development of phosphors chemistry has created a whole new industry.

It is a story which illustrates the value of what police departments speak of as "routine methods." As against every criminal brought to justice by the brilliant reasoning of a master-mind detective, a dozen are caught through routine investigation. Much scientific research, also, is routine. And it was routine investigation that was responsible for the development of phosphors. Scientists investigated thousands upon thousands of promising materials. As a result, it is known today that nearly 10,000 substances are fluorescent. Their names are catalogued. So a manufacturer who needs certain qualities of fluorescence has an excellent chance of finding what he needs somewhere in the list.

Nor is the reference to policemen so farfetched. Phosphors have proved to be very useful indeed in the detection of crime. When the black marketing of gasoline reached a dangerous height, for example, the Federal Government surprinted the coupons in your gasoline ration book with phosphorescent ink, which glowed under ultraviolet radiation. By examining the coupons in a darkened room, under ultraviolet light, it was possible to detect counterfeit coupons and send enforcement officers to any area in which a number of counterfeit tickets appeared.

In much the same way, ransom money demanded by a kidnaper may be invisibly marked with fluorescent dyes. A bank receiving one of the marked bills can put the police on the kidnaper's trail immediately. Checks may be printed with invisible inks, and laundry may also be invisibly marked.

Fluorescent lighting, in widespread use already in homes, shops, and office buildings, offers a good example of the work done by phosphors. The tubes used in fluorescent lighting operate on an entirely different principle from incandescent bulbs. They do not have a glowing filament of wire inside them. Instead, they are filled with a gas, which carries the electric current from one end of the long, slim tube to the other. The gas in turn activates a chemical coating on the inside of the tube. It is this inner coating which shines and sends out light. Very little of your electric current is wasted in the form of heat, using fluorescent tubes; nearly all of it is turned into light rays, with the result that a 15-watt fluorescent tube is considerably more efficient than a 100-watt bulb of the older type.

We have seen only the beginning of fluorescent lighting. As time goes on, it may change our whole notion of the way to illuminate our homes. Instead of overhead fixtures or table lamps, we may turn a whole wall, or a whole ceiling, into a light source—by making it of translucent plastic and concealing fluorescent tubes or coils behind it. We may come to regard our light fixtures as sources of health as well as sources of light.

Phosphors offer interesting possibilities for home decoration. Wallpaper with a pattern which glows in colors at night may be a bit too fantastic for your taste. On the other hand, fluorescent patterns which indicate a dangerous staircase, the location of the baby's crib, or the way to the bathroom have obvious practical value. Theatrical directors quite frequently use phosphors to obtain startling stage effects. And phosphors also have a practical value in other ways. Some theaters already have carpets with luminescent stripes. And a theater seat with a luminous marker may save you from the indignity of having a fat lady mistakenly sit on your lap in the belief that you are an empty chair.

Phosphors are available today which provide great variety in the way of color or length of afterglow. Some are set glowing by daylight, some by ultraviolet rays, some by cathode rays. Some glow for as long as twenty-four hours after radiation.

A list of important fluorescent materials is provided in "Luminescence of Liquids and Solids" by Peter Pringsheim and Marcel Vogel.[1] The materials are listed in various groups, such as aromatic carbohydrons and heterocyclic compounds, synthetic and natural dyestuffs, inorganic compounds and minerals, natural gems, etc. Numerous examples of uses and applications are given. One is the stage effect of producing an American flag from what appears under normal illumination to be a plain white cloth. On the area to be occupied by red stripes is applied cadmium borate; on that for the white stripes and the stars, magnesium tungstate; and on the blue field, calcium tungstate. These substances have been activated to produce fluorescence and, under the influence of ultraviolet light produced in high-intensity mercury lamps, they reflect the colors desired.

Another good book in this connection is "Fluorescent Light

[1] Pringsheim, Peter, and Marcel Vogel, "Luminescence of Liquids and Solids," Interscience Publishers, Inc., New York, 1943.

and Its Application" by H. C. Drake and Jack DeMent.[1] Lists of fluorescent minerals are provided and their principal sources are given. These authors state that Franklin, N.J., is easily the most noted locality in the world for the production of spectacular and colorful fluorescent minerals. From the zinc mines in that locality are obtained approximately 150 mineral species, most of which show luminescence. Some of the species are found nowhere else in the world. These minerals include the fire-red calcite and powerful green willemite. Other rich sources are located in California, Wyoming, New Mexico, Arizona, Texas, and Ohio. Prospectors equipped with lamps emitting ultraviolet light can detect such minerals when they have been found.

The mechanics of color television are described by Kingdon S. Tyler in his book "Modern Radio."[2] The following notes in this connection are derived from that book.

Objects in color appear to have more roundness and the outline is sharper. Color adds depth to the picture and makes it easier to define small objects. It provides a more interesting and lifelike reproduction of any scene. Various methods have been devised to produce color television. Some systems are electrical, some optical, and others mechanical. Some use two colors, some three colors. The three-color mechanical system breaks the picture down into three primary colors. Two sets of red, blue, and green color filters are arranged on a drum about 6 inches in diameter, which is revolved at 1,200 r.p.m. The basic principles are the same as for black and white transmission. Each time a filter passes the tube, one picture-scanning operation is completed. When the blue filter is in front of the tube, all the blue colors in the picture are registered. The filter allows more light to pass through where blue is present, only blue colors being scanned at that instant. The green filter takes care of yellow, also.

In the receiving set, corresponding color filters are arranged on a disk, which rotates at the same speed as the camera motor. The lens system on the camera is projecting a scene on the dissector

[1] Drake, H. C., and Jack DeMent, "Fluorescent Light and Its Application," Chemical Publishing Company of New York, Inc., New York, 1941.

[2] Tyler, Kingdon S., "Modern Radio," Harcourt, Brace and Company, Inc., New York, 1944.

tube. The impulses go to a transmitter and are sent out by a carrier to the receiver. One single scanning operation takes 1/120 second. There are six scanning operations (red, blue, green, red, blue, green) to one colored picture, which are completed in 1/20 second. The operations are so rapid that the eye sees a continuous, smooth flow of colors. All colors appear present at all times and they blend to effect the browns, purples, oranges, and other colors in the scene.

Colored television pictures were transmitted and received in 1928. Since then, much effort has been spent in trying to perfect a system that will be practical for popular use. On April 22, 1946, successful transmission of color television over the coaxial cable between Washington and New York was announced by Frank Stanton, president of the Columbia Broadcasting System. Earlier in the same month, Dr. Allen B. Du Mont, president of Allen B. Du Mont Laboratories, Inc., Passaic, N.J., announced to the public that black and white commercial television is a full-fledged reality, but that in his opinion "practical color television for the public is not yet in sight." The announcement invited all who were interested to send for a copy of the booklet "The Truth about Color Television."

Standards of color are established in the manufacture of many articles, and uniformity of color is carefully maintained. Among such products are paper products, pigments, paints, face powder, nail enamel, cosmetics, hair, teeth, foodstuffs, liquors, inks, fabrics, dyes, oils, crayons, glass, plastics, soft drinks, soap, packages, etc.

A small part of Jerome Beatty's very interesting article entitled "Putting the Rainbow to Work"[1] is quoted here.

> Already, in New Orleans, merchants on Baronne Street have colored their sidewalks green to attract attention to their stores; with such success that the merchants on Canal Street, in the same city, will meet competition by painting their sidewalks red! A few enterprising villages in Texas and California are coloring their pavements so that tourists will remember the towns. Soon, highways leading to cities may be painted in distinctive colors. We may read advertisements which bid us, "Follow the Green Line to Los Angeles!" or "Take the Red Route to Miami!"

[1] Beatty, Jerome, "Putting the Rainbow to Work," *The American Magazine*, August, 1930, pp. 34, 35, 82, 84.

But that isn't all. A movement is afoot to persuade Uncle Sam to color paper money—one-dollar bills, green; five-dollar bills, yellow; ten-dollar bills, blue; and so on—to make it easier for bankers and the rest of us to count our cash. Office buildings are beginning to appear in coats of varied hues. Even tombstones are to be adorned with outdoor, woodsy colors to beautify the cemeteries.

The following commentary is from an *Inter-Society Color Council News Letter.*[1]

"The Magic of Color"—under this title was a nearly full-page article in the *St. Louis Globe-Democrat* of (about) May 22. It dealt with the work, and showed a picture of Mr. George D. Gaw, Director of the Color Research Institute of America, and his associate Dr. Louis Cheskin. These Chicago color specialists say that color is the key to comfort, convenience, appearance, safety, and even health. Many familiar as well as original ideas are reported in the article. There were advocated brightly colored bases for electric stop signals and boulevard stop signs, instead of "camouflage" (diagonal black and white stripes); blue-green walls on bedrooms, which are also to have pink sheets; adjoining rooms painted with "split complements," the full complementary contrast being too strong and dangerous; tablecloths and napkins in complementaries, so that white napkins will not disappear into white tablecloths; blue slaughterhouses and kitchen-door screens to dispel flies; red, to repel mosquitoes; black roofs and white ceilings for doghouses, to make the dog more comfortable in winter; black auto driveways, to decrease the winter ice; white tarpaulins for ice wagons; avoidance of bright yellowish-green (chartreuse) drapes, to prevent nausea at work; orange in the danger areas of machines; bright-red stripes on washroom floors "to lift the loafer right up and out"; orange vertical faces of stairs to impel the lifting of the feet; green walls in operating rooms and green costumes for surgeons and nurses, to avoid troublesome afterimages; but the use of complementary afterimages by women wanting to know color schemes for their dress ensembles. We found this article interesting reading.

The following item was noted in a bulletin of the U.S. Department of Agriculture, called "Fabrics and Designs for Children's Clothes."[2]

[1] *Inter-Society Color Council News Letter* No. 60, Washington, D.C., July, 1945.

[2] "Fabrics and Designs for Children's Clothes," *Farmers Bulletin* 1778, U.S. Department of Agriculture, October, 1937, Superintendent of Documents, Washington, D.C.

The color of a playsuit should be gay, becoming, and pleasing to the youngster who will wear it. Colorful suits of red, green, and blue do not show soil as readily as do dark colors. Also they are more quickly seen by motorists and may help in preventing accidents.

From another publication of the U.S. Department of Agriculture, "Food and Home Notes,"[1] comes this suggestion:

> Grown-ups sometimes wear drab colors, but children like gaiety. Also, there's a safety factor to consider—a child's bright clothes may give the first slow signal to a motorist, or, in rural sections, to a hunter. So, when the main part of an outfit must be of a dull, uninteresting fabric, try adding bright trim or accessories. Dress up a little girl's black or gray coat with a red collar or a plaid ascot tie. Or complete the picture with a red cap or mittens.

Any procedure which attracts favorable attention in the course of business and which pleases the public is good advertising. In the operation of transportation facilities, such as buses, streetcars, subways, railways, air lines, and steamships, a good use of color creates a favorable impression on the passenger and is good advertising. Wherever the passenger has any choice, other considerations being equal, he will use the facility where the environment is most pleasant.

All operating companies are giving color serious consideration. In 1945 the Capital Transit Company of Washington, D.C. held their "Cavalcade of Progress." Its purpose was in part to show the public what is being done and planned for their convenience, safety, and comfort. This company had specially decorated a number of streetcars in various color combinations and requested the people to vote regarding their preferences.

In the early days of railroading in this country, locomotives and cars were painted in bright, attractive colors. As the years went by and smokestacks and dirt increased throughout the land, the choice for locomotives was uniformly black, while the cars were painted any color that would least show the grime. Now, with the progress of science, we are entering a new era in which

[1] "Food and Home Notes," *USDA* 1957–45, Oct. 22, 1945, U.S. Department of Agriculture, Office of Information, Washington 25, D.C.

color again enhances the "iron horse." The new breed does not belch forth clouds of smoke and ashes as its ancestors did faithfully for so many years. The Diesel locomotive is characterized by power, speed, silence, and cleanliness. These new engines are being invariably painted in bright, attractive colors. A few of the color combinations are noted as follows:[1]

Boston and Maine: Cherry red with golden yellow stripes.
Baltimore and Ohio: Deep blue, white, black, and gold.
The Milwaukee Road: Black and orange separated by golden yellow.
Burlington Route: Light gray and crimson separated by black.
The Southern: Navy blue and white separated by yellow.
Santa Fe: Cerulean blue and golden yellow separated by orange red.
Seaboard: Deep green, tan, yellow, and vermilion with separations of black and vermilion.
Great Northern: Light orange and light brown separated by yellow.
Western Pacific: Deep green and yellow separated by vermilion.
Rio Grande: Glossy black with five stripes of golden yellow.

Agriculture, Pest Control and Statistical Records

It has been noted that each wave length of visible light, as well as of ultraviolet, affects some process growth in plant life, and all visible light is necessary for complete growth. Acceleration of certain processes can be effected by a manipulation of the light. A full exposition of experiments, results, and conclusions in this connection is made in two reports by Earl S. Johnston, Assistant Director, Division of Radiation and Organisms, Smithsonian Institution: "Sun Rays and Plant Life,"[2] and "Plant Growth in Relation to Wave-length Balance."[3]

When the pinfeathers of young chickens come through the skin, the chicks frequently peck at each other and draw blood; then the sight of blood sometimes leads them to kill and eat each other. This condition can be overcome by confining them to an area bathed in red or green light. Either would tend to neutralize the

[1] From portfolios prepared by Electro-motive Division, General Motors Corporation, La Grange, Ill.

[2] *Smithsonian Institution Publication* 3432, 1937, Smithsonian Institution, Washington, D.C.

[3] *Smithsonian Institution Publication* 3446, 1938, Smithsonian Institution, Washington, D.C.

blood color, but the red light is preferred because of its activating quality. The green light would retard the activity and development of the chicks.

Bolls of cotton that open early in the season are bright; those opening after frost may be yellowish. Cotton that remains in the field after it has opened becomes darker and loses value.

The color of tobacco is an important factor in its sales value.

The beekeepers and packers of honey have to have some knowledge of the color of honey and have means for differentiating and classifying honey and beeswax colors. On the assumption that bees find their hives by sight, beekeepers in a number of foreign countries made a practice of painting the fronts of beehives in distinctive colors, to lessen the confusion of bees getting into the wrong hives. This is not done in this country, perhaps because it is generally known that bees in returning to their hives are guided by the sense of smell rather than by sight.

From a publication[1] of the U.S. Department of Agriculture, entitled "Vitamin A in Butter" (appropriately printed on yellow paper), the following is gathered:

> The vitamin A content of the butter was determined by using the antimony trichloride method, taking into account the color given by other materials in the butter which react with this reagent. . . . The carotene content of the butter was determined by washing the carotene solution in Skellysolve B with either 92-per cent methyl alcohol or 94-per cent diacetone alcohol to separate the carotene from the other pigments in the butter, and then reading the carotene fraction either with a colorimeter or a spectrophotometer.
>
> The above methods gave the results in micrograms of vitamin A and micrograms of carotene. In calculating the total vitamin A potency of the butter, 0.6 microgram of the carotene and 0.25 microgram of the vitamin A were each taken as equal to 1 International Unit of vitamin A. . . . There is ample experimental evidence that the vitamin A potency of milk, and also of the butter made from the milk, can be readily changed by increasing or decreasing the quantity of carotene in the cows' ration. The large increases in the vitamin A potency of the summer butter over the winter butter no doubt reflect an increase in carotene consumption by the cows when they were put on pasture.

[1] "Vitamin A in Butter," *Miscellaneous Publication* 571, U.S. Department of Agriculture, Washington, D.C., July, 1945.

The question as to whether or not there are conditions other than the quantity of carotene in the feed that affect the efficiency of its utilization by the cow has not been investigated adequately. It is obvious, however, from the large amount of experimental work in various laboratories, that any condition which tends to increase the lushness of pastures or the carotene content of winter-fed forages—either silages or hays—will increase the vitamin A potency of milk and butter very greatly. Hays that are cured in such a way that they retain their green color are rich in carotene, whereas hays that have lost their green color in curing may be very poor sources of carotene. Alfalfa hays may be rich sources of carotene or they may be worthless in this respect; timothy hays may vary manifold in their carotene content. Silages made from corn, hays, and other crops lose very little carotene during storage if properly made and stored, but the carotene content of the silage will depend on the carotene content of the crop at the time it was harvested and ensiled. Most crops decrease rapidly in carotene content as they mature or lose their green color.

The following information is reprinted from an *Inter-Society Color Council News Letter.*[1]

Color charts from which fruit growers can determine approximately the amount of nitrogen their apple trees receive from the soil, are now being printed. The preparation of the master standards and the matching of inks for printing the charts is reported in "Color Standards for McIntosh Apple Leaves; preliminary studies of leaf color in relation to nitrogen fertilizer," *Cornell University Agricultural Experimental Statistics Bulletin* 824, of which Walter C. Granville, well-known Council member, is coauthor with O. C. Compton, D. Boynton, and E. S. Philips, of Cornell University.

McIntosh apples are graded according to size and color and how well they will keep in storage. One of the factors which must be controlled, in order to produce the greatest possible number of apples of high quality, is the nitrogen content of the soil. Because too much as well as too little nitrogen will curtail his production and lower the quality of his crop, it is important that the fruit grower have some method for quickly and easily determining whether he is using the optimum quantity of nitrogen fertilizer. The amount of chlorophyll in McIntosh apple leaves depends upon the amount of nitrogen utilized by the tree. Since color of the leaf

[1] *Inter-Society Color Council News Letter* No. 61, Washington, D.C., September, 1945.

and chlorophyll content are related, a color chart could be made up for the grower to use in checking the effect of the nitrogen fertilizer he is applying. Samples of leaves were collected, and it was found that seven different greens could be distinguished conveniently by the eye. The percentages of nitrogen and of chlorophyll in leaves of each group were determined. Basic color specifications for each of the seven groups were set up from spectral reflectance curves run on the General Electric recording spectrophotometer at the Interchemical Research Laboratories.

The Bureau of Entomology and Plant Quarantine of the Agricultural Research Administration, advises thus:

Some of the primary or external symptoms which lead our scouts to suspect elms of having the Dutch elm disease consist of fading, yellowing, and browning foliage.

The internal symptoms which aid our scouts in classing an elm as a suspect and taking samples for culture consist of brownish streaks in the wood.

The Japanese beetle traps used for control and to determine the distribution of this insect pest were green and white for some years and then were changed to yellow, on the basis of improved catch of the beetles with the latter color.

This bureau uses leaflets in which various insect pests are reproduced in full color, to inform the public regarding control measures. The bulletin entitled "A Sticky Trap Board Used in Scouting for Pear Psylla"[1] includes this note:

A yellow color was decided upon after a series of preliminary tests indicated that yellow traps collected considerably more pear psyllas than other colors tested, which included orange, green, and white. The last mentioned was the least effective.

The following information has been supplied by the Fish and Wildlife Service of the U.S. Department of the Interior, Chicago 54, Ill.

[1] "A Sticky Trap Board Used in Scouting for Pear Psylla," *Bulletin* ET-220, Bureau of Entomology and Plant Quarantine of the Agricultural Research Administration, November, 1944.

In addition to the use of colored motion pictures and kodachrome slides, the Fish and Wildlife Service also makes regular use of color in various types of memoranda such as is the usual practice of business organizations.

There is also some employment of colors unique in our type of work. For instance, the dyeing of starfish with nile-blue sulphate for use in tracing their migrations. Recently also we determined to make use of the little-known fact that birds are very discriminating in selection of food by color, while rodents (rats, mice, squirrels, etc.) are color blind. Where it is necessary to place poison grains and other baits in the field for rodent control it seemed wise to apply certain dyes that disguised the normal color of such baits for the protection of birds. The result was surprisingly satisfactory. You will find an account of the experiment in the "Transactions of the Eighth North American Wildlife Conference" under the title "Birds, Rodents and Colored Lethal Baits," by E. R. Kalmbach.

The report referred to above is out of print, but the writer was permitted to examine a copy at the offices of the American Wildlife Institute, Investment Building, Washington, D.C. A summary of the report follows.

Quail, pheasants, and domestic poultry are immune to strychnine, a poison that has commonly been used to kill rodents; but many other seed-eating birds are not immune. In an effort to protect such birds from poisoning grains, the grains have been variously colored, with considerable success as concerns birds that are active in daylight. These birds are highly sensitive to color and have aversions to certain colors as applied to foods. Rodents cannot distinguish colors.

Rodent traps are set with various poisons, including thallium and the arsenics, London purple and Paris green. The color of such poisons is usually sufficient warning to the birds, but when poisons are used that have no color, some coloring is called for. Brilliant red seems to be the most generally effective color of warning for the birds when applied to seeds and grains; purple, the least effective. Aniline dyes of reds, oranges, greens, and blues have been used. Some farmers in Europe have applied brilliant dyes to seeds newly planted, in order to prevent them from being "pulled" by rooks, jackdaws, etc. The theory is that the bird digs up the seed, discards it because of the color, digs up a few more and, seeing

they are all of an unnatural color, departs from the field. These farmers have used red lead and colors of brilliant hues mixed with some adhesive material.

English sparrows have at times become pests and white arsenic was found to be effective in their case. It had no color and aroused no suspicion.

Knowing that hens are very sensitive to color, H. Elliott McClure, of Nebraska, experimented with setting hens by coloring the eggs in numerous ways. It was found that no color or combination of colors deterred the hen or affected the hatching in any way.

In connection with rodent control, an article entitled "Bad News for Brother Rat," by Clarence Cottam and Herbert S. Zinn,[1] stated that a new and very deadly bait for rats had been discovered. The poison is named "1080." In order to protect birds from this poison, certain experiments were made in coloring oat grains. In one field the oats were dyed yellow and in another green, while in a third they were left uncolored. In the uncolored area 28 birds were poisoned; in the yellow area, 9 birds; and in the green area, no birds at all. It was apparent that the birds had a definite aversion to seeds showing a green coloration.

The following information was furnished by the Agricultural Research Administration in Washington.

Photographs, charts, posters, motion pictures, transparencies, and similar material in color are used to a moderate extent in the reporting and publication of research and related informational activities. Color is necessary for the purpose of presentation of information on certain breeds of livestock, plants, and agricultural products. For instance, Department of Agriculture *Bulletin* 1244, dealing with stock poisoning plants of the range, contains many colored illustrations of such plants in natural colors. There are several loco weeds, for instance, which have different-colored flowers, and the use of color is necessary for their proper identification. The same comment applies to many other plants, the identification of which is aided by the use of color. Such identification, in a practical way, has probably prevented large losses of livestock from poisonous plants on western ranges.

Another publication, *Technical Bulletin* 790, deals with the improve-

[1] Cottam, Clarence, and Herbert S. Zinn, "Bad News for Brother Rat," *The Saturday Evening Post*, Nov. 10, 1945.

ment of Navajo sheep and various articles, such as rugs and blankets, made from their wool. This publication contains colored reproductions of such native goods.

In connection with poultry research, accurate records of the effect of feed on color of yolks of eggs are desirable. The same applies to educational exhibits portraying the color and feather patterns of chickens raised in various parts of the world. Large numbers of colored photographs were made at the last World's Poultry Congress, held in Cleveland, Ohio, a few years ago.

In connection with the National Poultry Improvement Plan, which this department administers, certain trade-marks which identify stages of breeding call for certain distinctive colors. We are about to issue a poster descriptive of these trade-marks, which necessarily must be in color if the poster is to serve the desired purpose adequately.

The Food and Drug Administration of our government is concerned with the use of colors in foods, drugs, and cosmetics. It is their duty to see that such colors are harmless and suitable for such uses, and that they be not employed to conceal damage or inferiority or to make the articles appear better or of greater value than they are. A great many of the laboratory techniques used in the examination of foods, drugs, and cosmetics involve changes of color and measurements of color values.

The Bureau of Dairy Industry, U.S. Department of Agriculture, reports:

We use colored cards, memoranda sheets, flags, and other similar aids for the purpose of speeding up the handling of a large number of records of milk production, by nearly a million cows listed in our files. We use these milk-production records, which come to us from dairy farmers, for the purpose of singling out the outstanding individuals and strains of dairy cattle. By comparing the production records of a large number of daughters of a bull with the records of the daughters' mothers, we get a picture of how good or how poor the bull may be as a transmitter of milk-production inheritance. We then publish a list of bulls with their so-called "proved-sire records" for the information of prospective bull buyers.

The Weather Bureau of the U.S. Department of Commerce advises thus:

The Weather Bureau makes use of color in a variety of ways. For example, different-colored balloons are used in making upper-air wind measurements, depending on the state of the sky at the time the balloon is released. For instance, a white balloon is used for a blue sky; yellow or red, when there is haze or smoke; and blue or black, when the sky is dark. It is necessary in this case that the observer follow the course of the balloon upward for the greatest possible length of time against any background.

The width of the color bands in a rainbow gives an indication of the size of the droplets which are suspended in the atmosphere and which form the bow by refraction and reflection of the sunlight falling upon them.[1]

The degree of darkening of filter paper by dust collected from air drawn through it gives a measure of atmospheric pollution.[2]

Various-colored overprints on meteorological charts produce contrasts in color which improve the accuracy of the data entered thereon and the efficiency with which it is entered.

It has been found by the Division of Agricultural Statistics of the Department of Agriculture that, when different colored papers were used for reports from cooperative observers, some colors gave a higher percentage of return than others.

Dun and Bradstreet, commercial advisors, periodically prepare and distribute to their subscribers, graphs depicting business trends, bankruptcy statistics, etc. These are reproduced in color to make the information more vivid and more easily understood.

It is doubtful if you could find a restaurant check, a theater ticket, a streetcar transfer, or a bank check without color. Postage stamps and the coupons of ration books are distinguished by different colors. Postal money orders and government checks have their standard colors.

In our modern civilization, color truly penetrates into every aspect of life.

Plant Operation

Color is now being extensively employed in factories and plants of all kinds. Its function here is to supplement illumination, aid

[1] See W. J. Humphreys, "Physics of the Air," McGraw-Hill Book Company, Inc., New York, 1929. This fact is not used as a basis for routine measurements, however.

[2] See *Monthly Weather Review*, Vol. 70, p. 225, October, 1942.

vision, and improve appearances. In working toward these ends, color is proved to have increased quantity and quality of production, to have reduced absenteeism and accidents, and in turn to have reduced insurance costs. By improvement of the appearance of the environment and the equipment, the morale of employees has been raised and the equipment has been maintained in better condition.

In September, 1941, Arthur A. Brainerd, Director of Lighting Service, Philadelphia Electric Company, and Matthew Denning, Director of Trade Sales, Finishes Division, E. I. du Pont de Nemours & Company, Inc., Wilmington, Del., presented a paper before the 35th Annual Convention of the Illuminating Engineering Society at Atlanta, Ga. This paper was entitled "Improved Vision in Machine Tool Operations by Color Contrast" and was a summary of experiments, findings, and conclusions of these authors. The following quotations are from their report.

The problem of seeing by artificial light is the problem of utilizing the light flux from lamps to produce favorable brightness and color contrasts. Every room is, in effect, a little world of its own. It has its own sun and sky, and its side walls correspond to surrounding hills. On a spring day out of doors we have an orange-white sun, blue sky, white fleecy clouds, green grass, gay flowers, and brown earth. Everywhere nature uses variety of hue and brightness to lessen the load on the eyes. It is much easier to judge the position of any object in sight under such conditions than in a desert or on the sea. Now our little indoor world more nearly approximates the great American Desert than a peaceful country side.

In the average factory we have a more or less white ceiling, and all too often the walls are also white, even down to the floor. Machines are most frequently green, deep gray, or black, affording almost no color or brightness contrast to the material under fabrication. In such surroundings, piling on high-level lighting does not produce the expected improvement in seeing. It is a great example of camouflage. . . . The most accurate seeing is only possible when the color of the various machine surfaces has been carefully selected to place the least burden on the eyes.

Light buff is the most suitable color where the material under fabrication is iron or steel, with light gray a close second. From the psychological angle, light blue offers possibilities which should not be over-

looked. When these figures were laid before the supervisory force for criticism, the main comments were that, while from a theoretical standpoint the idea was good, from the purely maintenance angle it was not practical to paint machines such a radical color as light buff. Accordingly, as a compromise, all machines were painted a medium gray, with light buff around the working area. The purpose was to utilize the luminous possibilities of the lighter finish and still satisfy maintenance requirements. Surprisingly, the combination seemed to perform better than any of the solid colors.

The above color arrangement has been in use since September, 1939. During the period of operation we have found the mechanics so convinced of its benefits, that they keep the light area clean without immediate supervision.

First, soft contrasts are easier on the eyes than abrupt changes in brightness. Secondly, making the tool area slightly lighter does tend to concentrate the attention on the work. Thirdly, a favorite contrast does high-light danger.

To those of us most closely connected with investigation, and to the various safety engineers who have been consulted, the most significant feature is the three-dimensional effect secured by controlled color contrasts. The work in machines so treated stands out in stereoscopic clearness that cannot be achieved with brightness contrasts alone.

Arthur A. Brainerd of the Philadelphia Electric Company and Robert A. Massey of E. I. du Pont de Nemours & Company, Inc., presented the paper "Salvaging Waste Light for Victory" at the Wartime Lighting Conference of the Illuminating Engineering Society in St. Louis, Mo., in September, 1942. A summary of this paper is presented in the following quotations:

In a previous paper the authors have discussed and established as a fact, that the ability to see quickly, accurately, and comfortably may be greatly improved by creating a favorable color contrast in the immediate vicinity of the work. Since the presentation of this thesis, many industrial establishments have adopted the practice and their experience has substantiated the soundness of these conclusions. The purpose of this paper is to extend the area studied to include not only the working area, but the entire room, and also to devise a means for the intelligent selection of colors for any specific seeing job. Our data show that, by means of a scientific use of color, it is practical to increase the illumination from

most light systems 100 per cent without any change in lighting equipment or any increase in wattage.

. . . Now let us consider the steps necessary to raise this illumination from 50 foot-candles to 100 foot-candles, with no increase in power consumption and with no change in equipment.

Let us start in, then, by refinishing the ceiling with a high-grade white or light-ivory paint, preferably having an eggshell or matte finish. It should be possible, with present finishes, to maintain an 80 per cent reflection factor.

Next, refinish the side walls with a slightly darker paint, such as light green, with a 65 per cent reflection.

Third, refinish all horizontal surfaces, benches, floors, tables, etc., in a paint of at least 40 per cent reflection factor.

Fourth, give all machines a standard "three-dimensional" finish.

. . . From the above discussion it is concluded that three-dimensional seeing, properly executed, can accomplish three definite tasks:

1. Provide positive visibility with finishes having high reflection factors, by means of adequate contrast in hue.

2. Provide an over-all contrast which is not too harsh to prevent continuous, comfortable seeing.

3. Provide a color sensation which is psychologically continuously pleasant and easy to live with.

. . . Spotlight buff fulfills these three conditions in a satisfactory manner. Its reflection value is high, 68 per cent . . . and its chroma is quite low. Psychologically, it has a high degree of acceptance.

Spotlight green, the second spotlight color, conforms even more closely to the theoretical specifications. It has a reflection value of 68 per cent, the same as spotlight buff . . . it is a yellow-green. Its chroma is low, although not so low as spotlight buff. Psychologically, it is acceptable in a wide range of industrial operations, and it is especially popular in the textile industry.

While future developments may call for other spotlight colors, it is believed that the two already in use will meet the requirements of most manufacturing operations.

Horizon gray is an achromatic, or neutral, color. As such, it will probably always occupy a prominent place as a background color. Its reflection value, 34 per cent, is high as compared with existing practices, although not so high as could be profitably utilized on horizontal surfaces.

The function of color as a part of the industrial seeing machine is to provide a controlled, mild stimulation and to increase visibility by means of suitable contrast. Brilliant colors, such as bright red or yellow,

stimulate impulsive action and have their place as danger and caution indicators. Under such conditions, pronounced stimulation is deliberately produced in order to get instant action. Preventive action must be instantaneous if accidents are to be reduced. Achromatic colors (in other words, gray) have a deadening effect if used to the exclusion of chromatic colors, *i.e.*, those having hue and chroma characteristics. Somewhere in between strong chromatic color and achromatic color lies the position of continuous, comfortable, accurate vision with a minimum of fatigue. The need of the correct degree of stimulation within the working area cannot be disputed. It is equally essential, however, that the hue and brightness of the surroundings, including floor and ceilings, must be of such character as to emphasize a return of the eyes to the working area and to have their greatest comfort while there. In addition, these areas should have an adequate reflection value to ensure the maximum use of multiple reflections. When all this is carefully worked out, it is possible to work continuously and comfortably over floors having a reflection factor of over 80 per cent.

. . . Three-dimensional seeing is that system of improving visibility on industrial machines by spotlighting the working area with light-colored paints of contrasting hues.

Horizon is that part of the wall immediately above the floor, when finished to aid illumination.

The National Lead Company (Dutch Boy), in their booklet "Let's Look at Paint," give the following statistics of the quantity of electricity required to maintain a light level of 10 foot-candles at a working plane 31 inches from the floor.

Colors	*Reflection factor, per cent*	*Wattage*
A Dark-gray ceiling	10	
Dark-gray side walls	10	1,530
B White ceiling	81	
Dark-gray side walls	10	990
C White ceiling	81	
Light-gray side walls	26	900
D White ceiling	81	
Cream side walls	75	495

A gloss or flat finish does not affect the quantity of reflected light, but does affect the quality.

The following note on the use of color by a manufacturer of high-grade shoes comes from a U.S. Department of Commerce bulletin:

> This concern painted the machines, equipment, and inside of its plant, and used gay, bright, and (where moving machinery was concerned) contrasting colors. All the colors of the rainbow were used. Employees took pride in voluntarily keeping clean the machines, floors, and immediate surroundings. It became an important factor in the profitable operation of the business because: (1) Eyestrain was eliminated, resulting in (a) amount of rejected products and damaged materials reduced to an insignificant minimum; (b) older employees able to compete with younger hands and keener eyes, both in quantity and quality of workmanship; (c) no reportable accidents for nine months. (2) Fatigue and nerve tension were eliminated. (3) Morale was improved—better attitude toward work, in keeping with the general brightness and cheer of surroundings.

The Food Machinery Corporation, manufacturers of heavy machinery in San Jose, Calif., use color in their factories as follows:

> *Machine Tools.* Three colors have sometimes been used. Bases have been painted one color; moving parts, a lighter contrasting color; and control handles, switches, etc., painted red or orange, for easy identification. This increases maintenance costs but aids in the training of new employees and makes a more attractive-looking shop.
>
> *Floors.* Aisles and other traffic areas are marked off with white lines. This prevents delays by having the aisles blocked, is a safety factor, and is conducive to good housekeeping.
>
> *Ceilings and Walls.* We generally paint these white in order to improve the lighting.
>
> *Fire Equipment, Sprinklers and Emergency Equipment.* These are generally painted red for quick location and identification.

The Public Buildings Administration, Washington, D.C., advises as follows:

> The Public Buildings Administration is at present studying the effect of changes in lighting and color on the efficiency and welfare of employees, but the information is not yet sufficiently complete to provide a basis for definite conclusions.

Earlier, we made studies of the effect of color on the efficiency of lighting in our machine shops and similar areas. Although no statistics of the psychological reactions were gathered, the reactions appeared to be favorable and the morale of employees was improved.

The National Safety Council, Washington, D.C., has issued a Safety Color Code. We have a similar color code in several shops and machine rooms operated by this organization. We propose to extend this program and to correlate accident data on a "before and after" basis.

The following information was obtained through the courtesy of the Metropolitan Life Insurance Company, New York.

A group of experts at Calco Chemical Company have completed an analysis of how color could be used throughout the company to prevent eyestrain and to make work areas pleasant and cheerful. The committee has prepared a list of color combinations for every location in the plant, based on a study of the light in any specific location. Calco people in every office, shop, and laboratory are offered a variety of colors from which to choose before a redecorating project is begun. A majority vote for any one of the combinations assures the group that kind of redecoration. Redecoration is complete. In the offices, for example, it includes painting walls, trim, file cabinets, and all furniture and fixtures.

The color combinations offered are based on a study of the light in any specific location. Light from without, as well as from artificial lighting, has a specific color temperature, which can be measured by instrument. The color scheme of any area is designed to complement these light sources. This way, a certain area can be painted so that light reflected will be as near that of a bright June day as is possible with color. North light, blue and clear, is best complemented in light tan. For eastern exposures neutral gray and coral is considered best for wall coloring by the committee. South light is yellow and calls for blue walls. Windows which face west let in light which is red and require green walls for the best effect. Light from both the old-type bulbs and white fluorescent tubes is yellow in cast and requires green. "Dalite" fluorescent lighting calls for tan.

As a result of extensive research and experimentation by various chemical and paint manufacturers, it is to be expected that all machines used in the manufacture of anything will be colored for efficiency.

E. I. du Pont de Nemours & Company, Inc., Wilmington, Del., are advertising their program of "Three-dimensional Seeing" and have issued a booklet under this title. It is illustrated in color to show the application of the principles disclosed in the findings of Arthur A. Brainerd, Matthew Denning, and Robert A. Massey, as previously outlined.

They are producing spotlight buff for ferrous metalworking operations and spotlight green for working brass, leather, and similar buff-colored materials. For the greater mass of the machine, they have developed horizon gray.

While thousands of organizations throughout the country are now benefiting from the use of the du Pont color plan, the names of a few are mentioned in the booklet. These include Ordnance Gauge Company, Philadelphia, Pa.; Oregon Shipbuilding Corporation, Portland, Ore.; Anchor-Hocking Glass Corporation, Lancaster, Ohio; Gregory Tool and Manufacturing Company, Detroit, Mich.; Drexel Furniture Company, Drexel, N.C.; Sacramento Air Depot, Sacramento, Calif.; American Radiator and Standard Sanitary Corporation, Buffalo, N.Y.; Tulsa Boiler and Machinery Company, Tulsa, Okla.; United Airlines, Chicago, Ill.; Rochester Button Company, Rochester, N.Y.; Blake Manufacturing Corporation, Clinton, Mass.; Scott Paper Company, Chester, Pa.; United Airlines, Cheyenne, Wyo.; Mary Muffet, Inc., St. Louis, Mo.; Endicott Johnson Corporation, Endicott, N.Y.; RCA Manufacturing Company, Inc., Camden, N.J.; Bliss and Laughlin, Inc., Buffalo, N.Y.; and Avondale Mills, Sylacauga, Ala.

The Pittsburgh Plate Glass Company, Pittsburgh, Pa., have developed and are advertising their program along these lines for the use of color in many situations, including plant operation. The general program is called "Color Dynamics" and they have issued a special booklet describing its principles and use in plants.

The objectives of Color Dynamics are

1. To promote continuity of employment.
2. To improve efficiency of operation.
3. To maintain quality of production.

In essence, Color Dynamics is based on principles directly opposed to camouflage practices. To camouflage an object, color is used to hide and

obscure. In Color Dynamics, color is used to high-light, reveal, and emphasize.

They have developed 10 focal colors and vista green for use on machines. Their program of color includes walls, ceilings, floors, aisles, and mobile equipment, as well as everything else used in a given area. Only by such over-all application can maximum benefits be derived.

The Glidden Company, Cleveland, Ohio, call their industrial color program "Sight Perfection," which results from light reflection plus color correction. They have developed the E-Z-C and Vismatic colors and overall schemes for their application to everything within a given area. The E-Z-C colors are moss green, light moss green, ocean green, light ocean green, standard gray, light gray, light blue-gray, maroon, and cream. The Vismatic colors are Vismatic orange, Vismatic buff, and Vismatic green. Their booklet "Sight Perfection" provides information about the objectives and procedures of their program and is beautifully illustrated with full-color reproductions of shops and machines.

Faber Birren, in an article, "Color in the Plant,"[1] provides a very interesting exposition of the use of color in industrial plants. In the introduction he makes it clear that

> Color is not an end in itself. If color is to be used at all in the plant, it must be used with purpose. . . . Factory decoration is not interior decoration in any sense of the word. In principle, one does not get people to work harder and more accurately by inspiring them with color. Quite the contrary, the trick is to establish a seeing condition that automatically, in and of itself, makes the task easier. In other words, color does not stand around on the side lines like a cheerleader. It digs in with the worker's own problems of seeing, directing his attention rather than competing for it. It is integral with production and not a thing apart.

In any industrial situation he favors white ceilings and walls with a slightly grayish cast because they serve their purpose best and are less distracting. He states:

[1] Birren, Faber, "Color in the Plant," *Factory Management and Maintenance*, Vol. 103, No. 2, February, 1945.

On large pieces of factory equipment like ovens, driers, and power presses, massive areas of color are avoided to prevent a "world's fair" appearance. Average psychological responses are capitalized and color is employed to offer visual compensation for dark and vaultlike spaces, or for unfavorable exposure to high temperatures. Even in the foundry, where a general coat of paint may last little longer than the time required to put it on, color is specified in certain smaller but nonetheless choice locations, where it will give the worker some visual clarity through the fog of his surroundings.

In this article a description is given of the specific colors used by the following companies for the particular conditions of their plants. Allied Kid Company, Wilmington, Del.; Ashland Corporation, Jewett City, Conn.; Consolidated Edison Company, New York; Davis & Geck, Inc., Brooklyn, N.Y.; Henry Disston & Sons, Philadelphia, Pa.; Marshall Field & Company, Chicago, Ill.; Pabst Brewing Company, Milwaukee, Wis.; Parke, Davis & Company, Detroit, Mich.; Radio Corporation of America, Camden, N.J.; Servel, Inc., Evansville, Ind.; John B. Stetson Company, Philadelphia, Pa.; Sylvania Electric Products Company, Salem, Mass.; Paul Whitin Manufacturing Company, Northbridge, Mass.

The article is illustrated with full-color reproductions of industrial situations. One shows the stair well walls, at Ashland Corporation, of peach with dado of medium blue. Another shows a scene from the Paul Whitin Manufacturing Company. Machines are light gray, switch boxes blue, guards yellow, ceilings white. Red is reserved for fire-protection equipment. Light green, with dark-gray dado, is used for walls and columns, to avoid sharp contrasts in light and dark. A corner in the Magnetic Metal Company's plant, Camden, N.J., shows one brick wall painted white, another light yellow. The brass fire extinguisher is surrounded by an area of red. The body of a large machine is a medium gray and the worker wears a blue coverall. The caption of one illustration reads, "Good use of color has transformed the rewinding department at Ashland Corporation from a typical mill room into one that women enjoy working in. They say the soft-yellow walls give them a real 'lift'."

Codes

One important use of color today is to help distinguish an area or an object that has special significance. Color dramatizes it, emphasizes it, and makes it easily recognized, apart from its surroundings.

In this connection, codes have been developed in various fields, some of which have world-wide recognition, some are national, and others are understood only by the organization that uses them. The signal flags used on board ships have world-wide significance. Most traffic signals are at least nationally recognized. Other codes have been adopted by certain industries and others have been created by individuals for their own convenience. As signals, colors are symbols; they convey a message and are effective only as their meaning is understood by those concerned.

In his article "Color in the Plant," cited before, Birren states:

> A satisfactory code, which coordinates the best of tradition and precedent, has recently been developed and endorsed by safety authorities. In this code, yellow is reserved for strike-against hazards; orange is standard for hazards likely to cause serious injuries, such as cuts, shocks, burns; green is for the identification of first-aid equipment; red for fire protection devices; blue for caution and to indicate machinery and equipment not to be moved or operated; and gray (white or black) for traffic marks, waste receptacles, and other less vital things. The code has had the benefit of practical use in several factories and is under consideration as a nation-wide standard.

The Railroad Code includes:

Red: Danger, stop.
Yellow: Proceed with caution.
Green: All clear.
Blue: Caution, men working.
Purple: Stop.

H. S. Fairbank, Deputy Commissioner of the Public Roads Administration, Washington, D.C., elaborates on the above as follows:

> In the highway field, color has application principally in traffic-control devices. The use of red, green, and yellow in traffic signals is

almost universal, although in some localities red and green alone are still found. The use of these colors to indicate *Stop* (red), *Go* (green), and *Proceed With Caution* (yellow) was taken from earlier railroad practice, and probably (at least, as to red and green) goes even further back to marine light signals. So far as we know, the choice of colors is quite arbitrary; that is to say, there is no particular reason, other than conventional use, for making one color mean "stop" and another "go." It is recognized, however, that the colors red, green, and yellow are well chosen for distinctive signals. A bluish green and a somewhat orange red can be distinguished even by those who are partially color-blind. Specifications for traffic signal lenses have been set up by the Institute of Traffic Engineers in precise terms of chromaticity. The legal meaning of the colors displayed by traffic signals, as generally accepted, is set forth in the model Uniform Act Regulating Traffic on Highways.

In traffic signs the color yellow has for about twenty years been standardized for warning signs. Nearly every state follows the standards of the American Association of State Highway Officials and uses a yellow background with black lettering or symbols for signs demanding caution or slow speed. The choice of yellow was presumably based partly on the accepted meaning of yellow in railroad signaling, but more on the fact that yellow is bright enough to contrast well with the black message, and at the same time distinctive enough to be conspicuous in most surroundings. This same yellow has been adopted by the American railroads for painting certain maintenance equipment, and a similar but slightly more orange shade has been accepted as the national standard for school bus bodies.

The Manual on Uniform Traffic Control Devices, which sets forth the standards approved by the American Association of State Highway Officials and other agencies, also specifies that signs regulating parking shall use red lettering on a white background where parking is prohibited at any time or all the time, and green lettering where parking is permitted only under certain restrictions.

White and black, though not strictly "colors" are also used in highway signs. All informational, directional, and regulatory signs are standardized with black lettering or symbols on a white ground. Some highway departments, however, believe a reversal of "colors" to use white lettering on a black ground gives greater legibility, and design some of their signs accordingly.

In pavement markings, black, white, and yellow have been used. Black center lines on cement concrete pavements are not uncommon, though white is more usual. On "black-top" pavements, white or yellow

must be used. Most states prefer white lines on both black-top and concrete pavements, though a few use yellow in the belief that it is more visible in fog or that it wears better. A number of states use yellow in an additional center stripe to mark "no-passing zones," where it is unsafe to overtake and pass the vehicle ahead. This marking of no-passing zones is not well standardized at present, and numerous variants can be seen. Some states use only a single color for pavement markings of all kinds.

Where bridge piers or other obstructions stand in or very close to the roadway, they are commonly painted with alternating black and white stripes, to make them as conspicuous as possible.

In other highway uses, the color of paint is ordinarily a matter of chemical expediency. Black paint is usual on steel bridges, for practical rather than esthetic reasons. Aluminum paint is also used, both because of its qualities as a protective coating and because it aids visibility at night. Bridge handrails are often painted white for visibility. Where other colors are used, the choice is usually for esthetic reasons.

In Canada and other parts of the British Empire, both mailboxes and fire-signal boxes are red.

D. Harrington, Chief, Health and Safety Branch, Bureau of Mines, U.S. Department of the Interior advises as follows:

Color, particularly during the war years, has been used to advantage in campaigns for the reduction of accidents. The American Standards Association, New York City, has been compiling an overall color safety code for adoption by industry. Many industrial organizations paint the moving or operating parts of machinery a contrasting color from the fixed parts, in order to indicate the existence of a physical hazard. Guards on machinery parts are painted in a contrasting color in a manner which makes their removal readily noticeable.

The color safety code adopted by some industries is that each color or its symbol is used to indicate a distinct hazard or establish some specific identification.

One of the most specific examples of the successful use of color in coal mines is the distribution of rock dust on the sides, roof, and floors in mine passageways, although primarily the dust is used to limit explosions; the light color of the dust when placed on the mine surfaces increases visibility and thus helps in reducing accidents. The safety holes along haulage roads in some coal mines are whitewashed to distinguish them readily.

Another noteworthy example of the use of color is found in Senator Rouyn Mine in Canada. The various pipe lines in the mill are painted different colors, and charts of the colors are posted throughout the mill. This has reduced lost time when making pipe changes and in making new installations.

The National Safety Council and the American Society of Mechanical Engineers recommended these uses:

Red: Fire-protection equipment.
Yellow or orange: Dangerous materials, acids, gases.
Green: Safe materials, water, brines, etc. (Gray, white, or black is also approved in this connection.)
Blue: Protective materials, antidotes for poison fumes, etc.
Purple: Valuable materials, caution against waste.

Safe Practice Pamphlet No. 64 of the National Safety Council (U.S. Bureau of Mines and Chemical Section) specifies a code for gas-mask canisters to be used for protection against various combinations of gases, smokes, etc.

The Interstate Commerce Commission requires that the following dangerous products be labeled in the following manner for shipment:

Poisons, explosives, poisonous gases, and tear gas: Red type on white ground.
Inflammable liquids and fireworks: Black on red.
Acids: Black on white.
Inflammable solids and oxidizing materials: Black on yellow.
Compressed gases: Black on green.

Tank cars unloading inflammable liquids, etc., are indicated by a blue sign with white letters. In some cases the dome of the car is painted to indicate its contents and to expedite handling.

Advertising, Selling, and Buying

Many millions of dollars are spent each year by manufacturers and others to bring their products and services to the attention of the buying public. A large percentage of sales results directly from good advertising, and good advertising and selling involves good use of color. One color demands attention, another persuades to buy.

In full color is the magic formula for selling merchandise. Not only does merchandise displayed in natural color make a fine display, which attracts the attention of the prospect, but it anticipates the inevitable question, "How will it look in my home?" Color gives action and attention value to the most static of objects. Collections of merchandise that singly are uninteresting may be combined in an effective way and graced with color. Then they cease to be mere articles of merchandise and become colorful bits in the kaleidoscope of merchandising in color.

Without any doubt, color sells goods. Advertisements of food products, fabrics, automobiles, seeds, tours, tree surgery, or almost anything else pays greater dividends when presented with color than without.

Some tests have been conducted to try to find out which colors have desirable attention value and which have sales appeal. One test indicated that black on white had the greatest attention value for men and that red on white got most attention from women. Another test indicated that dark blue had the most pronounced advertising influence on women and violet on men. Dark green had the least influence on both.

In his book, "Selling with Color," Faber Birren points out that simple colors that can be easily remembered have sales value. He states, "Only about 18 colors can be named by the average person with any assurance that others will know what he is talking about, and these colors will be found to comprise the best sellers in almost every line of mass market merchandise in existence." He lists these colors as follows: red, orange, yellow, green, blue, violet (or purple), pink, buff (ivory or cream), flesh, (or peach), lavender (orchid), brown, maroon, tan, white, gray, black, gold, silver.

Color as an aid to selling has to be considered for specific articles. The same color could be very effective in one instance and yet completely fail in another. A survey disclosed that more 10-cent toothbrushes that had red handles were sold than those with handles of any other color, but that more 25-cent toothbrushes having amber handles were sold. Coffee sales in one instance were increased when the packer changed the colors of the container to yellow and orange, of weak chroma. A candy manufacturer using a blue wrapper increased his sales by changing to a red wrapper.

Jewelry has been found to sell best with a background of strong yellow and purple. More people are said to respond to advertising mailed on light-red, yellow, and green paper than to that on white.

In the service field, there is a story of a resort hotel that catered to the "tired businessman." Suddenly their clientele began to fall off without any apparent reason.

When questioned, some of the old patrons said their last visit had not been restful but they didn't know why. A color expert discovered that the gardens, where many of the guests took their ease, had, that year, been planted with a predominance of red flowers. The vibrations of red from the garden were so high that the guests of the hotel were stimulated instead of relaxed. The red flowers were taken out and blue and white flowers put in their place. Within a short time, the hotel's business was back to normal.[1]

Louis C. Flaherty reports

When first on the market—Spearmint was in a *green* wrapper—the color of fresh *mint*. It went fine. The export market expanded. In China—it didn't go. It seems green, in China, was like the number 13 with superstitious people. So—Wrigley changed to the magenta pink they were using before the war. It was the "good-luck" color of China. Sales picked up immediately.

H. Baron & Co., Inc., manufacturers of pure food specialties, Linden, N.J., state as their experience that brochures and labels attractively presented in harmonious colors provide the greatest sales stimuli.

We thank S. Q. Shannon, Director of The Greeting Card Industry, New York City, for the following observations:

The greeting-card business depends almost entirely upon judicious use of color in securing visual appeal in its products but the use of color is so much a part and parcel of our operations that I do not believe anyone has made a special analysis of its use in relation to producing greeting cards.

In passing, it might be of interest to note that experience has shown

[1] From "Color Strategy for Wartime America," a booklet edited by Roberta Ross, Director of the Decorating Studios, Time-tested Paint Laboratories, Cleveland, Ohio, 1943.

us that the use of yellow to any excessive degree quickly reduces the salability of greeting-card designs and we have likewise found that use of certain traditional colors that are more or less recognized as being tied in with the celebration of the various holidays is not always consistent.

For instance, excessive use of pink or, in fact, use of pink to any great degree in valentines results in reduced sales. Likewise, an excessive amount of red in Christmas cards invariably causes consumer resistance.

In general, it appears that the basic fundamentals of color usage—namely, careful blending of colors, reproduction of suitable color harmonies, and avoidance of the garish and blatant use of color—must always be adhered to in order to produce the most pleasing effects.

D. L. Moberg, of Tested Papers of America, Inc., Chicago, Ill., describes the use of color that they have found to have sales value with their products:

The colors were chosen by our package designer, Mr. Robert Sidney Dickens, to illustrate our three brands, *Test-mark*, *Test-line*, and *Testex*. The top grade of each line has been designated as *Test-mark* and is identified predominantly by a magenta color (bordering, however, more on the red-red blue than on the red-blue).

The medium grade is called *Test-line* and is portrayed by a rich blue. Our standard grade, *Testex*, is identified by a deep green.

Our experience has shown us that these colors are distinctive enough to stand out from their neighbors on the shelves of the retail store. Our belief in using these colors also is that they are dominant, appealing, friendly, and lively.

A most ingenious and effective use of color in bringing products and services to the attention of the buying public is found in the Diorama. This display is handled by the Terminal Electric Signs Company, New York City, and was conceived by Edward H. Burdick, President of the Diorama Corporation. It includes modeling, sculpture, painting, and lighting, plus simple animation, which effects a three-dimensional realism.

The display has been seen at various expositions and world's fairs and is at present in use in busy sections of several cities. The cabinet of the Diorama is about 14 inches deep and those in the Union Station, Washington, D.C., measure about 6 feet high and 8 feet wide.

The displays include scenery or other background, real or synthetic objects in full or partial relief arranged to appear in true perspective, brilliant coloring, dramatic lighting, and the effect of fascinating movement in one or more parts, produced by changing lights. It is attention compelling and is undoubtedly most effective in selling the products or services advertised.

Color and lighting, which go hand in hand in any situation, are being given more and more consideration in all store displays.

Important to successful selling is the use of light to attract the eye to the merchandise displays. The use of light in the work of the display artist is much more interesting and has many more possibilities than the lighting of a theater stage, because in the theater, the mood, the setting, and the script have already been created. The display artist, on the other hand, sets his own stage, determines the mood, designs the setting, and where necessary writes the script. His possibilities are limited only by his own ideas and the budget on which he operates.

Wall, niche, and case lighting provide diffused light, and a pleasing color blend of light comes from the combination of light sources which contributes to the atmosphere of the entire interior. Dramatic lighting of a display is the most effective way to attract immediate attention to it, by making it stand out from its surroundings. Our entire seeing process is based on contrast; a light-colored object against an equally light background is almost invisible, regardless of the level of illumination. The brightest object attracts attention and the level of illumination, to be attention compelling, must be higher than its surroundings. With spotlights, footlights, and border lights used, if desired, in combination with color, the intensity, direction, or color of the light on the display and its brightness is wholly within the command of the display artist.

Window displays have twice the color and lighting problem that interior displays have, because the windows are seen each day under totally different conditions—by strong, glaring daylight and by total artificial light at night. It is, therefore, necessary to plan such colors as will be equally effective in windows under the two sets of conditions. Through the combination of light and of color used with light, there is no limit to the possibilities for window displays.[1]

The Stecher-Traung Lithograph Corporation, Rochester, N.Y., produced a brochure in 1945 for advertisers entitled "The Selling

[1] "New Lighting and Display," *Display on Display*, August, 1945.

Power of Full Color." This 24-page booklet demonstrates graphically the force of color in advertising and is full of practical, interesting, and useful information, which includes advice on the preparation of art work for color reproduction.

Color and Food[1]

Everyone automatically judges fruit, vegetables, meats, cheese, butter, etc., largely by color. If you are going to buy, the color has to conform with your knowledge of the standard.

Flour. Flour is bleached white and aged by chemicals that do not affect its nutritive properties. Buckwheat flour can be made as white as wheat flour, but the characteristic dark color is from particles of the hull that are permitted to remain in it.

Butter. If the cow has eaten plenty of green grass, the butter is sufficiently yellow. If not, it is colored with a harmless vegetable dye. Unsalted butter is usually sold uncolored. Much of cold-storage butter is artificially colored.

Pepper. Black pepper is the dried and ground immature berry, containing its black coating. White pepper is from the mature berry, with the coating removed.

Cloves. The dried, unopened flower buds of the clove tree are known as "cloves." The best are of light purplish-brown color.

Mace. Mace is the blood-red covering over the shell of the seed that contains the nutmeg. When dried, it turns dark yellow.

Sugar. Brown sugars are such because of the refiner's syrup that they contain. All the syrup has been removed from white sugar and it is bleached. Imitation syrups are artificially flavored and colored. Molasses is a by-product of the manufacture of cane sugar. The higher grades are usually bright amber in color. Honeys are graded white, light amber, amber, and dark. The light-amber varieties are usually of higher grades.

Cheese. Except for the few varieties that are sold white, all cheeses are artificially colored.

Grapefruit. There is no difference in flavor between the pale-

[1] Much of the information in this section was gleaned from "Food Buying Today," by Alexander Todoroff, The Grocery Trade Publishing House, Chicago, Ill., 1939.

yellow fruit and the russet variety. The latter have acquired their tinge from the rust mite, which lives only on the skin.

Limes. Limes contain more citric acid than lemons do. The best juice is obtained from green limes, before they have turned yellow. The color of high-grade lime juice is a pale straw. A lower grade may appear a reddish color.

Oranges. Some varieties of oranges, when fully ripe and sweet, are bright green in color. In the locality where these oranges are grown, they are marketed that way; but if they are to sell in nonproducing areas, they must be dyed orange. This coloring process does not affect the fruit in any way.

Bananas. Bananas must be harvested in a green state in order to survive shipping. When the banana is removed from the plant it grows on in the tropics, it has reached its full growth and is mature; but the starches in it have not yet turned to sugars. When this takes place, the pulp becomes too soft to permit any extensive handling. The process of ripening and turning from green to yellow requires a temperature of about 70° and can be hastened if the fruit is left in a paper bag. Bananas will not ripen in an icebox. A banana is best for eating when the skin is a deep yellow and flecked with brown spots. The flavor of bananas that have ripened on the plant is inferior to those that are picked green.

Tomato Juice. Straight tomato juice is almost clear and yellowish. The product that is on sale is produced from the entire tomato, except for the skin, core, and seeds. The red color is that of the pulp. If the juice purchased appears less red, it is because more juice and less pulp has been provided.

Tea. Tea leaves are green when picked. A bright, coppery color results from oxidation during fermentation. If, after fermentation, the leaves are dried over heat, they turn black. If the leaf is dried without fermenting, it retains its original green color.

Coffee. The appearance or color of the coffee bean is no indication of its quality. The proof is in the cup alone.

It is to be expected that the color of canned produce will approximate the reproduction on the label. Any processed foods that contain artificial coloring are required to be so marked on the label.

Cans with lacquered lining are used in packing certain prod-

ucts containing acids and having a high natural color. The lining prevents the bleaching effect that would be caused by the action of the tin coating of plain cans on the coloring matter.

The pinkish color of canned pears is due to heat applied at the time of canning. It may happen to the best grade and does not affect the flavor.

Red raspberries and strawberries packed in syrup have a better color than those packed in water.

Green beans and wax beans differ only in color.

The best cauliflower is white or creamy white, with no tinge of yellow or green.

Cucumbers should be green, with no trace of yellow.

Onions may be yellow, red, or white. The color has no relation to quality or flavor.

Potatoes should be yellowish white inside, not yellow.

A fully ripened sweet potato will not change color on being cut. When unripe, it will turn green.

For the best flavor, tomatoes should be permitted to ripen on the vine and not be picked green.

Yellow turnips have a stronger flavor than white ones.

Green vegetables will keep their color if cooked in little or no added water. The addition of soda to preserve the color destroys a large part of the vitamin content.

Dried beans are available in every color of the rainbow and in black and white, besides. Some varieties have markings.

Salmon comes almost in white, in golden red, various pinks, and brown-colored flesh. The coloration does not affect the taste or the nutrition. It is an indication of the fatness of the fish when caught, although the flesh of some varieties is paler than others, even with maximum fatness.

The gills of fresh fish should be bright red; the eyes should be bright and clear.

Ducks and geese have only dark meat.

Turkeys should have no purple tinge to the flesh, as this marks an old bird. Any fowl that is quick-frozen suffers no change in color when it is thawed, but if it is frozen again it will become discolored.

Brown eggs and white eggs have equal taste and nutrition. The

quality of the egg contents depends on the hen's feed and the handling of the egg.

Yolks vary from pale yellow to deep orange, depending on the amount of corn and green stuff that the chicken eats.

The color of good beef is bright cherry red, with creamy-white fat.

Good veal is grayish pink. The bones are reddish and the fat, clear white.

Lamb is pinkish red and the bones are reddish.

Mutton is deep, dull red and the bones are white.

Pork is light grayish pink and the bones have a slight tinge of red.

The coloring material used in many carbonated soft drinks is caramel, made by heating dry sugar.

All food colorings on sale, whether in paste or liquid form, are harmless in the small amounts in which they are generally used.

To Remove Accidental Color from Fabrics

Blood

1. *Fresh:* Wash in cold or lukewarm water until stain disappears.
2. *Old:* Soak in 1 gallon of water with 2 tablespoons ammonia.
3. *On heavy material:* Apply paste of raw starch and water. Allow to dry, then brush.

Candle Wax

Scrape off excess wax.

1. Place blotting paper underneath and over and press with warm iron.
2. Remove wax with cleaning fluid.

Chocolate

1. Sprinkle with borax, then moisten with water. Let stand, then pour on boiling water.
2. Remove grease with cleaning fluid, then remove color with hydrogen peroxide.

Coffee: Pour on boiling water from height of 12 inches. Wash as usual.

Fruit

1. Treat as for coffee except peach, pear, or raspberry, for which use bleach or frost.
2. Spread with glycerine for 2 hours, then wash as usual.

Grass: Cover with paste of starch and cooking soda. For delicate colors, wash in alcohol or ammonia and water.

Ink

1. Cover with kerosene and rub well. Rinse in fresh kerosene. Launder as usual.
2. Use commercial bleach on white cotton or linen.

Indelible ink: Saturate with turpentine and ammonia, let soak, then rinse with soap and water.

Iodine: If washable, moisten with water and baking soda, let dry, and brush off. If not washable, sponge with denatured alcohol.

Iron rust: Let stand with salt and lemon juice on spot. Wash as usual.

Lipstick: Rub soap on dry stains and let stand several hours, then wash as usual.

Mercurochrome: Use peroxide of hydrogen; launder.

Mildew: Let stand with lemon, salt, starch, and soft soap for 2 days, then rinse in clear water, or use commercial bleach.

Oil paint: Sponge with turpentine. Follow with soap and water.

Cellulose paint: Sponge with mineral spirits. Follow with soap and water.

Wine: If still wet, apply salt and let stand, then pour on boiling water. If dry, wet stain and coat with powdered starch and let stand in the sun for 2 hours. Repeat if necessary. Launder.

The matter of successfully removing accidental color from fabrics is not always a simple task. Consideration should be given to the kind of fabric and the nature of the color to determine what remover can be safely and effectively employed. The best booklet that has come to this writer's attention in this connection is "Stain Removal From Fabrics, Home Methods"[1] by Margaret S. Furry, Asst. Textile Chemist, Textile and Clothing Division, Bureau of Home Economics. This 29-page booklet describes in detail correct methods of removing over 100 substances from cotton, linen, wool, three kinds of rayon, silk, nylon, vinyon, etc. Some high lights from the booklet follow.

Treat the stain promptly while it is fresh. First try to sponge

[1] The booklet is listed as *Farmers Bulletin* 1474, U.S. Department of Agriculture, 1942. If it is still in print, it can be purchased from the Superintendent of Documents, Washington, D.C.

it away with cold water. Try carbon tetrachloride for greasy stains. Avoid hot water, as it sets many stains. Test for color change on sample of fabric. Use light brushing motions; don't rub. Neutralize acids with alkalies and alkalies with acids. Rinse well; never let chemical dry on cloth. Some acids destroy cotton and linen; even lemon juice or vinegar will do it, if left too long on fabric. Some alkalies are ammonia water, washing and baking soda. All bleaches will rot cotton and linen if they are allowed to remain on the cloth more than a minute or two. The safest bleaches are sodium perborate and hydrogen peroxide.

Among the useful cleaning fluids are carbon tetrachloride, gasoline, benzene, turpentine, ether, acetone, alcohol. The last three might change the color of fabric, and alcohol should be mixed with two parts of water. Fruit stains should be treated at once. Warm or boiling water may be successful, but should never be used on silk or wool. Stretch the fabric over a vessel and pour the water on from a height of about 2 feet. Do not use soap, as the alkali may set the stain. Another method for fruit stains is to sponge well with cold water, work glycerine into the stain, and let it stand for several hours; apply a few drops of white vinegar and let it remain a minute or two; then rinse well. Tomato juice and catsup stain can be removed by sponging with cold water, working glycerine into the stain, letting it stand a half hour, washing with soap and water. Grass stains can sometimes be removed with soap and hot water.

Acknowledgment is given to the following sources of information. See also Part Seven.

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Crisp, Quentin: "Color in Display," Chemical Publishing Company of New York, Inc., New York, 1938.

Douglas, Lester: "Color in Modern Printing," Frederick H. Levey Company, New York, 1931.

Fiene, Dr., and Saul Blumenthal: "Handbook of Food Manufacture," Chemical Publishing Company of New York, Inc., New York, 1938.

PART SEVEN

References

21

ORGANIZATIONS

A few of the many organizations that are more than ordinarily concerned about the development and use of color are listed herewith. Many of these have been helpful to the writer in the preparation of this book.

All Color Co., Inc., New York, N.Y.
American Artists Professional League, New York, N.Y.
American Association of Textile Chemists and Colorists, Lowell, Mass.
American Ceramic Society, Columbus, Ohio.
American Medical Association, Chicago, Ill.
American Psychological Association, Ann Arbor, Mich.
American Society for Testing Materials, Philadelphia, Pa.
American Writing Paper Corporation, Holyoke, Mass.
Ansco, a Division of General Aniline & Film Corp., Binghamton, N.Y.
Bakelite Corporation, Bound Brook, N.J.
Bausch & Lomb Optical Co., Rochester, N.Y.
Birren, Faber, & Co., New York, N.Y.
Bureau of Visual Science, American Optical Co., Southbridge, Mass.
Calco Chemical Division, American Cyanamid Co., Bound Brook, N.J.
Cambridge Tile Manufacturing Co., Cincinnati, Ohio.
Canada Printing Ink Company, Toronto, Canada.
Celanese Corporation of America, Chicago, Ill.
Collins & Aikman Corp., Philadelphia, Pa.
Color Production Service Corp., New York, N.Y.
Color Research Corp., New York, N.Y.
Color Research Institute of America, Chicago, Ill.
Congoleum-Nairn, Inc., Kearny, N.J.
Container Corporation of America, Chicago, Ill.
Corning Glass Works, Corning, N.Y.
Design, Inc., St. Louis, Mo.
Disney, Walt, Productions, Hollywood, Calif.
Dow Chemical Co., Midland, Mich.
Eastman Kodak Co., Rochester, N.Y.
Electric Testing Laboratories, New York, N.Y.
Federation of Paint and Varnish Production Clubs, Philadelphia, Pa.

Fiatelle, Inc., New York, N.Y.
Forstmann Woolen Co., Passaic, N.J.
Foxboro Co., Foxboro, Mass.
General Aniline & Film Corp., Easton, Pa.
General Dyestuff Corp., New York, N.Y.
General Electric Co., Cleveland, Ohio.
Hammermill Paper Co., Erie, Pa.
Harmon Color Works, Haledon, N.J.
Holophane Co., Inc., New York, N.Y.
Hommel, W. E., Co., Pittsburgh, Pa.
Illuminating Engineering Society, New York, N.Y.
Institute of Design, Chicago, Ill.
Institute of Ophthalmology, New York, N.Y.
Institute of Paper Chemistry, Appleton, Wis.
Interchemical Corporation, New York, N.Y.
International Paints, Ltd., Montreal, Quebec, Canada.
Inter-Society Color Council, Washington, D.C.
Macbeth Daylighting Corp., New York, N.Y.
Merck & Co., Rahway, N.J.
Merrimack Mfg. Co., New York, N.Y.
Milton Bradley Co., Springfield, Mass.
Munsell Color Co., Inc., Baltimore, Md.
National Bureau of Standards, Washington, D.C.
National Carbon Co., Inc., Cleveland, Ohio.
National Formulary, American Pharmaceutical Association, Washington, D.C.
National Lead Co., New York, N.Y.
National Paint, Varnish & Lacquer Association, Washington, D.C.
National Safety Council, Washington, D.C.
North Star Woolen Mills, Minneapolis, Minn.
Norton Co., Worcester, Mass.
Onondaga Pottery Co., Syracuse, N.Y.
Optical Society of America, Massachusetts Institute of Technology, Cambridge, Mass.
Pacific Mills, New York, N.Y.
Pharma Chemical Corp., New York, N.Y.
Plaskon Division, Libby-Owens-Ford Glass Co., Toledo, Ohio.
Pratt & Lambert, Inc., Buffalo, N.Y.
Proctor & Gamble Co., Ivorydale, Ohio.
Pylam Products, New York, N.Y.
R-B-H Lacquer Base Co., Bound Brook, N.J.

Riegel Textile Corp., New York, N.Y.
Rohm & Haas Co., Bristol, Pa.
Smith, Alexander, & Sons Carpet Co., Yonkers, N.Y.
Society of Motion Picture Engineers, New York, N.Y.
Strobolite Co., New York, N.Y.
Technical Association of the Pulp and Paper Industry, New York, N.Y.
Technicolor Motion Picture Corp., Hollywood, Calif.
Textile Color Card Association of the United States, New York, N.Y.
Tintometer, Ltd., The Colour Laboratory, Milford, Salisbury, England.
Traffic Service Corp., Chicago, Ill.
U.S. Pharmacopoeial Convention, Philadelphia, Pa.
U.S. Testing Company, Hoboken, N.J.
Watson-Standard Co., Pittsburgh, Pa.
Weston Electrical Instrument Corp., Newark, N.J.

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MANUFACTURERS

The following is a selected list of manufacturers of colors for various industries. Complete classified lists of manufacturers of colors and related industries are provided in *Thomas' Register of American Manufacturers*, by Thomas Publishing Co., New York, N.Y. (published annually).

Acme White Lead and Color Works, Detroit, Mich. (dry).
Alabastine Co., Grand Rapids, Mich. (dry).
Alston-Lucas Paint Co., Lyons, Ill. (paint, oil).
American Aniline Products, Inc., New York, N.Y. (acid, alizarin, aniline, chrome, textile, food, gasoline, paint, oil).
American Artists Color Works, Inc., Brooklyn, N.Y. (artists').
American Crayon Co., Sandusky, Ohio (artists', textile).
American Cyanamid Co., New York, N.Y. (dry).
American Dyewood Co., New York, N.Y. (aniline).
American Pigment & Chemical Co., Inc., Noblestown, Pa. (cement, brick, dry).
American Resinous Chemicals Corp., Peabody, Mass. (leather).
American Waterproofing Corp., Brooklyn, N.Y. (cement, brick).
Ansbacher-Siegle Corp., Brooklyn, N.Y. (chrome, cosmetic, dry, ink, perfume, soap).
Arco Co., Cleveland, Ohio (paint, oil).
Aridye Corp., Fair Lawn, N.J. (dry, textile, silk screen).
Atlantic Sales Corp., Rochester, N.Y. (food).
Baker Extract Co., Springfield, Mass. (food).
Baker Paint & Varnish Co., Jersey City, N.J. (paint, oil).
Barclay Chemical Co., New York, N.Y. (aniline, artists', cement, brick, dry, ink).
Behlen, H., & Bro., Inc., New York, N.Y. (aniline, oil, grease).
Berghausen, E., Chemical Co., Cincinnati, Ohio (burnt sugar, food).
Bessire & Co., Inc., Indianapolis, Ind. (food).
Binney & Smith Co., New York, N.Y. (cement, bricks, dry, ink).
Bissell Varnish Co., Bridgeport, Conn. (paint, oil).
Blacks, Inc., Casmalia, Calif. (cement, bricks).

Blanke-Baer Extract and Preserving Co., St. Louis, Mo. (food).
Blue Ridge Talc Co., Inc., Henry, Va. (brick, cement).
Bowey's, Inc., Chicago, Ill. (food).
Bradford, James, Co., Wilmington, Del. (paint, oil).
Bridges, Smith & Co., Inc., Louisville, Ky. (paint, oil).
Burdsol, A. S., & Co., Indianapolis, Ind. (dry, paint, oil).
Burnett, Joseph, Co., Boston, Mass. (food).
Burton, W., & Co., Inc., Brooklyn, N.Y. (food).
Bush, W. J., & Co., Inc., New York, N.Y. (burnt sugar, food).
Butcher, L. H., Co., San Francisco, Calif. (dry).
Cabot, Samuel, Inc., Boston, Mass. (cement, bricks, mortar).
Calco Chemical Div., American Cyanamid Co., Bound Brook, N.J. (alizarin, chrome, dry, food, ink).
California Ink Co., San Francisco, Calif. (dry, ink).
Calvert Aniline & Chemical Co., Cincinnati, Ohio (aniline).
Cambria Paint Co., Johnstown, Pa. (cement, brick).
Carbic Color & Chemical Co., Inc., New York, N.Y. (acid).
Carpenter-Morton Co., Boston, Mass. (paint, oil).
Ceramic Color & Chemical Mfg. Co., New Brighton, Pa. (cement, brick, ceramic, glass).
Chapman & Smith Co., Chicago, Ill. (food).
Chemical & Pigment Co., Inc., Div. The Glidden Co., Cleveland, Ohio (dry).
Ciba Co., Inc., New York, N.Y. (alizarin, aniline).
Cincinnati Fruit & Extract Works, Cincinnati, Ohio (food).
Clinton Metallic Paint Co., Clinton, N.Y. (cement, bricks, dry, metallic).
Coddington, E. D., Mfg. Co., Milwaukee, Wis. (dry).
Columbian Carbon Co., Magnetic Pigment Div., New York, N.Y. (dry, ink).
Commonwealth Color & Chemical Co., Brooklyn, N.Y. (acid, basic, textile, paint, oil).
Connors, William, Paint Mfg. Co., Troy, N.Y. (dry).
Corona Chemical Div. of Pittsburgh Plate Glass Co., Milwaukee, Wis. (chrome, dry).
Coyne, George S., Chemical Co., Inc., Philadelphia, Pa. (dry).
Daigger, A., & Co., Chicago, Ill. (dry).
Dahls & Stein, Inc., Newark, N.J. (beer, burnt sugar).
Detroit White Lead Works, Detroit, Mich. (cement, bricks).
Devoe & Raynolds Co., New York, N.Y. (artists', dry, paint, oil).
Diehl, William A., & Co., New York, N.Y. (artists', dry).
Dodge & Olcutt Co., New York, N.Y. (food, perfume, soap).

Drakenfield, B. F., & Co., Inc., New York, N.Y. (ceramic, glass, chrome, dry).
Dreyer, P. R., Inc., New York, N.Y. (cosmetics, food).
Dunne, Frank W., Co., Oakland, Calif. (paint, oil).
du Pont de Nemours, E. I., & Company, Inc., Wilmington, Del. (cement, brick, ceramic, glass, dry, ink, paint, oil).
Dye Specialties Corp., Jersey City, N.J. (basic).
Dykem Co., St. Louis, Mo. (food).
Eaton Clark Co., Detroit, Mich. (aniline).
Egan & Hausmann Co., Inc., Long Island City, N.Y. (paint, oil).
Ene Laboratories, Inc., New York, N.Y. (cosmetic).
Enterprise Paint Mfg. Co., Chicago, Ill. (dry).
Ewing Fox, M., Co., New York, N.Y. (cement, brick, dry).
Favor-Ruhl Co., New York, N.Y. (ceramic, glass, paint, oil).
Fear, Fred, & Co., Brooklyn, N.Y. (food).
Federal Color Laboratories, Inc., Cincinnati, Ohio (dry).
Ferro Enamel Corp., Cleveland, Ohio (ceramic, glass, dry).
Florasynth Laboratories, Inc., New York, N.Y. (food, perfume, soap).
Food Materials Corp., Chicago, Ill. (food).
Friedrichs, E. H. & A. C., Co., New York, N.Y. (paint, oil).
Frigid Food Products, Inc., Detroit, Mich. (food).
Fuller, W. P., & Co., San Francisco, Calif. (paint, oil).
Geigy Company, Inc., New York, N.Y. (air-brush, spirit, alizarin, chrome, textile, ink, paint, oil, silk screen, wax flowers).
General Color Co., Inc., Newark, N.J. (dry, dental, food).
General Paint Corp., San Francisco, Calif. (paint, oil).
Gillespie Varnish Co., Jersey City, N.J. (paint, oil).
Gladding, McBean & Co., San Francisco, Calif. (cement, brick).
Glass Crafters Div., Chicago, Ill. (glass).
Glidden Co., Cleveland, Ohio (paint, oil).
Globe Paint Works, Inc., Williamsport, Pa. (paint, oil).
Griffith Laboratories, Chicago, Ill. (food).
Griffiths, K. F., & Co., Inc., New York, N.Y. (dry).
Grumbacher, M., New York, N.Y. (artists', paint, oil).
Hachmeister, Inc., Pittsburgh, Pa. (cement, brick, paint, oil).
Hansen's Laboratory, Inc., Little Falls, N.Y. and Milwaukee, Wis. (food).
Harmon Color Works, Inc., Paterson, N.J. (cosmetic, dry, ink).
Harper, James A., Supply Co., Kansas City, Mo. (food).
Harshaw Chemical Co., Cleveland, Ohio (ceramic, glass, chrome, dry, ink).

Heller, B., & Co., Chicago, Ill. (food).
Hellmuth, Charles, Printing Ink Corp., New York, N.Y. (dry).
Hemmerdinger, L., & Co., New York, N.Y. (paint, oil).
Hewlett Bros. Co., Salt Lake City, Utah (food).
Hilton-Davis Chemical Co., Cincinnati, Ohio (dry).
Holland Color & Chemical Co., Holland, Mich. (dry).
Hommel, O., Co., Carnegie, Pa. (glass).
Hooker Glass & Paint Mfg. Co., Chicago, Ill. (dry, paint, oil).
Horn, A. C., Co., Long Island City, N.Y. (cement, brick).
Huber, Frederick W., Inc., New York, N.Y. (food).
Hurty, Peck & Co., Indianapolis, Ind. (food).
Imperial Paper & Color Corp., Pigment Color Div., Glen Falls, N.Y. (alizarin, carbon paper, typewriter ribbon, chrome, dry, ink).
Interstate Brick Co., Salt Lake City, Utah (brick).
Jamestown Paint & Varnish Co., Jamestown, Pa. (cement, brick).
Johnson, Charles E., & Co., Philadelphia, Pa. (dry).
Johnson, Oliver, & Co., Inc., Providence, R.I. (paint, oil).
Kentucky Color & Chemical Co., Louisville, Ky. (cadmium, chrome, dry, ink).
Keuffel & Esser Co., Hoboken, N.J. (artists').
King, E. & F., & Co., Inc., Boston, Mass. (cement, brick, chrome, dry, leather, paint).
Kohnstamm, H., & Co., Inc., New York, N.Y. (food, carbon paper, typewriter ribbon, cosmetic, dry, ink, leather, paint, oil).
Lasting Products Co., Baltimore, Md., (cement, brick, dry, ink, metallic, paint).
Lawrence, W. W., & Co., Pittsburgh, Pa. (distemper, paint, oil).
Longman & Martinez, Inc., Brooklyn, N.Y. (paint, oil).
Lowe Brothers Co., Dayton, Ohio (paint, oil).
Lucas, John, & Co., Inc., Philadelphia, Pa. (dry, paint, oil).
McDougall-Butler Co., Inc., Buffalo, N.Y. (paint, oil).
McKesson & Robbins, Inc., New York, N.Y. (food, burnt sugar).
McKesson-Van Vleet-Ellis Corp., Memphis, Tenn. (food).
McNulty, Joseph A., New York, N.Y. (artists', ceramic, glass, cement, brick, dry).
Magnus, Mabee & Reynard, New York, N.Y. (food, perfume, soap).
Marschall Dairy Lab., Inc., Madison, Wis. (food).
Marshall, John G., Inc., Brooklyn, N.Y. (paint, oil).
Martini Artists Color Laboratories, Long Island City, N.Y. (artists').
Martin-Senour Co., Chicago, Ill. (paint, oil).
Mason Color & Chemical Works, East Liverpool, Ohio (ceramic, glass).

Masury, John W., & Son, Inc., Baltimore, Md. (paint, oil).
Mathews Paint Co., Los Angeles, Calif. (paint, oil).
Maumee Color Co., Maumee, Ohio (food).
Mepham, George S., Corp., East St. Louis, Ill. (cement, brick).
Mineral Pigments Corp., Muirkirk, Md., (cement, brick, chrome, dry, ink).
Minnesota Linseed Oil Paint Co., Minneapolis, Minn. (paint, oil).
Minnesota Mining & Mfg. Co., St. Paul, Minn. (basic).
Monsanto Chemical Co., St. Louis, Mo. (dry).
Moore Leland Paint & Oil Co., Charlotte, S.C. (dry, paint, oil).
Moore, Benjamin, & Co., New York, N.Y. (paint, oil).
Morrow Extract Co., Brooklyn, N.Y. (food).
Moser, Charles, Co., Lyons, Ill. (paint, oil).
Mound City Paint & Color Co., St. Louis, Mo. (dry, paint, oil).
Muralo Co., Inc., New Brighton, Staten Island, N.Y. (artists', distemper).
Murphy Varnish Co., Newark, N.J. (paint, oil).
Murray Co., Boston, Mass. (food).
National Aniline Division, New York, N.Y. (alizarin, aniline, carbon paper, typewriter ribbon, textile, food, oil, grease, perfume, soap).
National Lead Co., New York, N.Y. (dry).
New York Color & Chemical Co., Inc., Belleville, N.J. (aniline).
Noggle, S. W., Co., Kansas City, Mo. (food).
Nyanza Color & Chemical Co., New York, N.Y. (aniline).
Phoenix Color & Chemical Co., New York, N.Y. (aniline, dry).
Pierce, F. O., Co., Long Island City, N.Y. (paint, oil).
Pittsburgh Plate Glass Co., Pittsburgh, Pa. (paint, oil).
Pratt & Lambert, Inc., Buffalo, N.Y. (paint, oil).
Premier Chemical Corp., Cleveland, Ohio (paint, oil).
Preservaline Mfg. Co., Brooklyn, N.Y. (food).
Price Flavoring Extract Co., Chicago, Ill. (food).
Prince Mfg. Co., Bowmanstown, Pa. (cement, brick, dry).
Pysol Paint Mfg. Corp., Hawthorne, N.J. (paint, oil).
Reardon Co., St. Louis, Mo. (dry).
Reichard-Coulston, Inc., New York, N.Y. (cement, brick, dry).
Reichhold Chemicals, Inc., Detroit, Mich. (alizarin, carbon paper, typewriter ribbons, chrome, dry, ink).
Rensche, L., & Co., Newark, N.J. (ceramic, glass).
Republic Chemical Corp., New York, N.Y. (chrome).
Retort Pharmaceutical Co., Long Island City, N.Y. (food).
Ricketson Mineral Color Works, Milwaukee, Wis. (cement, brick).

Ronan, T. J., Co., Inc., New York, N.Y. (paint, oil).
Ruxton Products, Inc., Cincinnati, Ohio (air-brush, spirit, artists', silk screen).
St. Louis Surfacer & Paint Co., St. Louis, Mo. (dry).
Samuel, J. A., & Co., New York, N.Y. (ceramic, glass).
Sauer, C. F., Co., Richmond, Va. (food).
Schilling, A., & Co., San Francisco, Calif. (food).
Schrack, C., & Co., Philadelphia, Pa. (paint, oil).
Seminole Pigment Co., Warren, Ohio (dry).
Senefelder Co., Inc., New York, N.Y. (dry, ink).
Sethness Products Co., Chicago, Ill. (burnt sugar, food).
Sewall Paint & Varnish Co., Kansas City, Mo. (paint, oil).
Shepherd Chemical Co., Cincinnati, Ohio (ceramic, glass).
Sherwin-Williams Co., Cleveland, Ohio (carbon paper, typewriter ribbons, chrome, dry, ink, paint, oil).
Sinclair & Carroll Co., Inc., New York, N.Y. (dry).
Sinclair & Valentine Co., New York, N.Y. (dry).
Smith, J. Lee, Co., Inc., New York, N.Y. (cement, brick, chrome, dry, ink).
Standard Ultramarine Co., Huntington, W. Va. (dry).
Stange, William J., Co., Chicago, Ill. (food).
Stanley Doggett, Inc., New York, N.Y. (artists', cement, brick, carbon paper, typewriter ribbon, ceramic, chrome, cosmetic, dry, glass, ink, leather, metallic, soap).
Steelcote Mfg. Co., St. Louis, Mo. (paint, oil).
Styron-Beggs Co., Newark, N.J. (food).
Sun Chemical & Color Co., Div. General Printing Ink Corp., Harrison, N.J. (artists', carbon paper, typewriter ribbon, cosmetic, dry, ink).
Superior Printing Ink Co., New York, N.Y. (dry).
Synthetic Iron Color Co., Richmond, Calif. (cement, brick).
Talens School Products, Inc., New York, N.Y. (school colors, papers).
Tamms Silica Co., Chicago, Ill. (cement, brick, dry earth).
Thompson & Co., Oakmont, Pa. (paint, oil).
Toch Bros., Inc., Staten Island, N.Y. (dry, cement).
Tone Bros., Des Moines, Iowa (food).
Truscon Laboratories, Inc., Detroit, Mich. (cement, brick).
Twitchell, S., Co., Philadelphia, Pa. (burnt sugar).
Uhlfelder, Leo, Co., New York, N.Y. (basic).
Uhlich, Paul, & Co., Inc., New York, N.Y. (dry, carbon paper, typewriter ribbon).
Union Starch & Refining Co., Columbus, Ind. (burnt sugar).

United Indigo & Chemical Co., Ltd., Boston, Mass. (alizarin, aniline).
U.S. Gutta Percha Paint Co., Providence, R.I. (paint, oil).
Valentine & Co., Inc., New York, N.Y. (paint, oil).
Vane-Calvert Paint Co., St. Louis, Mo. (paint, oil).
Virginia Dare Extract Co., Inc., Brooklyn, N.Y. (food).
Vita-Var Corp., Newark, N.J. (alizarin, aniline, ceramic, glass, chrome, paint).
Vitro Mfg. Co., Pittsburgh, Pa. (cement, brick, ceramic, glass, dry).
Wadsworth-Howland & Co., Boston, Mass. (paint, oil).
Wagner, Charles A., Co., Inc., Philadelphia, Pa. (chrome, dry).
Warner-Jenkinson Mfg. Co., St. Louis, Mo. (food).
Waterall, William, & Co., Philadelphia, Pa. (paint, oil).
Weber, F., & Co., Inc., Philadelphia, Pa. (air-brush, spirit, artists', paint, oil).
Wesco Waterpaints, Inc., Boston, Mass. (artists', dry).
Western Dry Color Co., Chicago, Ill. (dry, ink).
Whittaker, Clark & Daniels, Inc., New York, N.Y. (cement, brick, cosmetic, dry, ink, perfume, soap).
Williams, C. K., & Co., Easton, Pa. (cement, brick, dry, metallic).
Williamson, D. D., & Co., Inc., Long Island City, N.Y. (burnt sugar).
Wine, S. J., Coffee Co., San Diego, Calif. (food).
Witco Chemical Co., New York, N.Y. and Chicago, Ill. (cement, brick, dry).
Wood & Selick, Inc., New York, N.Y. (food).
Yarnall Paint Co., Philadelphia, Pa. (paint, oil).
Zinsser & Co., Inc., Hastings-on-Hudson, N.Y. (dry, alizarin).

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